2009-12

The integration of the Naval Unmanned Combat Aerial System (N-UCAS) into the future naval air wing

McGuire, Michael

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/4484

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE INTEGRATION OF THE NAVAL UNMANNED COMBAT AERIAL SYSTEM (N-UCAS) INTO THE FUTURE NAVAL AIR WING

by

Michael McGuire

December 2009

Thesis Co-Advisors: John Mutty
Daniel Nussbaum

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** December 2009		**3. REPORT TYPE AND DATES COVERED** Master's Thesis
4. TITLE AND SUBTITLE The Integration of the Naval Unmanned Combat Aerial System (N-UCAS) into the Future Naval Air Wing			**5. FUNDING NUMBERS**
6. AUTHOR(S) Michael McGuire			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE** A
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14. SUBJECT TERMS unmanned, Aerial Vehicle, UCAS, aircraft carrier, air wing, cost estimation			**15. NUMBER OF PAGES** 92
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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THE INTEGRATION OF THE NAVAL UNMANNED COMBAT AERIAL SYSTEM (N-UCAS) INTO THE FUTURE NAVAL AIR WING

Michael McGuire
Lieutenant, United States Navy
BS and BA, Bucknell University, 2003

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2009

Author: Michael McGuire

Approved by: Captain (Ret.) John Mutty
Thesis Co-Advisor

Dr. Daniel Nussbaum
Thesis Co-Advisor

William Gates, PhD
Dean, Graduate School of Business and Public Policy

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ABSTRACT

This MBA Project investigates the use of unmanned vehicles, specifically the Navy-Unmanned Combat Air System (N-UCAS), which can be employed and deployed in novel ways to gain access in the access denied surface domain due to the proliferation of anti-ship ballistic missiles. The capabilities of N-UCAS, coupled with a new employment/deployment model, have the potential to allow the Navy to maintain the forecasted capacity of the future power projection fleet while reducing the number of carriers. The savings from the reduction in the carrier fleet could allow smaller crafts, such as the Joint High Speed Vessel (HSV) and the Littoral Combat Ship (LCS), to be procured in larger numbers to aid in the shortfalls that the current Naval Force has in Maritime Security and Cooperative Engagement (MSCE) capacity.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEW	Airborne Early Warning
ASW	Anti-Submarine Warfare
BOE	Basis of Estimates
CATCC	Carrier Air Traffic Control Center
CCA	Carrier Control Area
CSG	Carrier Strike Group
EA	Electronic Attack
ESG	Expeditionary Strike Group
EW	Electronic Warfare
FRS	Fleet Readiness Squadron
HSV	High Speed Vessel
ISR	Intelligence, Surveillance, and Reconnaissance
JSF	Joint Strike Fighter
LCC	Life Cycle Cost
LCS	Littoral Combat Ship
LO	Low Observable
LSO	Launch Safety Officer
MCO	Major Combat Operations
MCS	Mission Control Segment
MOC	Maritime Operations Center
MOOTW	Maritime Operations Other Than Warfare
MSCE	Maritime Security and Cooperative Engagement
MSS	Maritime Security Strategy
NCCA	Naval Center for Cost Analysis
N-UCAS	Naval-Unmanned Combat Aerial System
O&S	Operations and Support
POM	Program Objective Memorandum
PRI-FLY	Primary Flight Control
QDR	Quadrennial Defense Review

RDT&E	Research, Development, Test, and Evaluation
ROMO	Range of Military Operations
SAR	Selected Acquisition Reports
T1	First Production Model
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Aerial Vehicle
USN	United States Navy
UV	Unmanned Vehicle
WBS	Work Breakdown Structure

ACKNOWLEDGMENTS

My sincere thanks go to my entire family who has supported me throughout my entire life. Without their support, I would not be able to serve my country and continue to challenge the "norm"—virtually enabling me to plan and develop an innovative framework for my entire life.

Another thank you goes to Admiral Hogg, Bill Glenney, and the entire Chief of Naval Operations (CNO) Strategic Studies Group (SSG). Without their guidance and professional development, my thought process would have been stove-piped into my tactical knowledge of submarines.

With respect to the SSG, I would like to give an additional thanks to Commander (CDR) Carrigan, CDR Gordon, CDR Hodges, CDR MacDonald, Colonel Kirby, and Captain Richard. Without the guidance of two senior Surface Warfare Officers, a Sea, Air, and Land (SEAL) Officer, an Aviator, a Post Major Command Marine Corps Aviator, and a Post Major Command Submarine Officer, my knowledge of force structure and the future Naval needs would be severely lacking. A special thank you goes to Steve Koepenick who drove me to success and forced me to push my ideas to the forefront.

I could not have accomplished this thesis without the cost estimating knowledge of Dr. Nussbaum, and the deep understanding of the Navy's budget that Captain Mutty possesses. Their guidance was paramount in the professional and timely development of my thesis.

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I. THE NAVY IS ABOUT SEA CONTROL

Looking to the future, the Navy is clearly evolving from being a platform centric to a network centric force.[1]

A. INTRODUCTION

The United States Navy (USN) has developed a Maritime Security Strategy (MSS) that outlines the Range of Military Operations (ROMO) based on core capabilities. The core capabilities can be broken down into three subsets: Maritime Security and Cooperative Engagement (MSCE), Power Projection, and Access Generation.[2] The Carrier Strike Group (CSG) and Expeditionary Strike Group (ESG) can accomplish the Power Projection roles for the USN, but the threat has changed. By attacking the USN at the "low" and "high" ends of warfare, (from Maritime Operations Other Than Warfare (MOOTW) to Major Combat Operations (MCO)) the enemy has created a capacity shortfall for the USN in MSCE and a capability gap in access generation. The aircraft is the cornerstone of the USN's power projection and center of credible combat force, but the increasing life cycle costs have created both the aforementioned issues. The addition

[1] Benjamin S. Lambeth, *Air Power at the Dawn of A New Century* (Santa Monica, CA: RAND Corporation National Defense Research Institute, 2005), 96.

[2] Access Generation and Power Projection have been separated out as opposed to coupled due to the proliferation of anti-ship ballistic missiles. This proliferation has caused the surface domain to be denied to the carrier. The Navy must regain access of the surface domain by using the domains that are not denied, such as undersea and the air. The MSS outlines Sea Control and preventing war as core capabilities, but these are strategic imperatives and are necessary for the Navy to accomplish all of the other core capabilities.

of the Navy Unmanned Combat Air System (N-UCAS) provides a possible solution for meeting the capability gaps in access generation while providing new employment/deployment models for air wings and aircraft carriers that could reduce the needed number of carriers to project power—allowing the funding necessary to increase the capacity of the fleet to perform MSCE.

N-UCAS is a carrier air wing capable unmanned aerial vehicle. The UCAS is in the advanced capability and prototype development phase under BA-7 for Research, Development, Test, and Evaluation (RDT&E).

> The Navy Unmanned Combat Air Vehicle (UCAS) designed for autonomous launch and recovery as well as operations in the Carrier Control Area (CCA), is comprised of a Low Observable (LO) planform Air Vehicle Segment, a Mission Control Segment (MCS) and a government led Aircraft Carrier Integration Segment. The scope of the Navy UCAS effort includes design, development, integration, and validation of an unmanned, LO planform Air Vehicle Segment and MCS in the land-based and shipboard environments. Evaluations will be conducted to investigate MCS interfaces with shipboard systems such as primary flight control (PRI-FLY) displays, Landing Safety Officer (LSO) displays, and Carrier Air Traffic Control Center (CATCC) stations. The Navy UCAS program will be structured to match program resources to United States Navy (USN) objectives/constraints with the goals of identifying and maturing critical technologies and reducing the risk of carrier integration of a UCAS. In previous budget requests, separate Project Units were identified for the Navy UCAS CV-Demo (PU 3178) and Technology Maturation (PU 3191) efforts. Candidate Technology Maturation efforts include transformational communications, advanced integrated propulsion, CV suitable materials, LO sensors and apertures, sense and avoid functionality (all operating in a LO

environment), autonomous operations (software algorithms and interfaces), and computer resource data storage and access systems. The demonstration and the technology maturation efforts will develop data to support a follow-on acquisition milestone decision. The Navy has consolidated Project 3191 into Project 3178 beginning in FY10.[3]

The thesis will examine the ability to complement the air wing with the use of N-UCAS in both strike and ISR missions.

B. BACKGROUND

The development of the aircraft carrier extended the reach of combat aircraft in WWII achieving a goal that has only been surpassed by the development of ballistic missiles. "The carrier revolution greatly increased the range over which naval forces could deliver combat power."[4] The aircraft carrier development gave the United States a means to accomplish the ROMO of the time: fleet defense, land strikes, close support of ground troops, and anti-submarine warfare. Once the capability was developed the need for range became a strategic imperative for nations through the Cold War. The race for reach had begun.

At the end of WWII, the United States operated 99 carriers, including 28 fleet carriers and 71 CVEs. Within five years of the ascension to power, the carrier fleet was

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[3] Office of Under Secretary of Defense (Comptroller), “Defense Budget Materials, Office of the Under Secretary of Defense (Comptroller) FY2009,” Department of Defense, mhttp://www.defenselink.mil/comptroller/defbudget/fy2009/index.html (accessed July 21, 2009).

[4] Thomas P. Ehrhard and Robert O. Work, *Range, Persistence, Stealth, and Networking: The Case for Carrier-Based Unmanned Combat Air System* (Washington, D.C.: Center for Strategic and Budgetary Assessment, 2008), 30.

reduced to 11 carriers and four escort carriers.[5] The reduction in the carrier fleet lead to a noticeable range disadvantage over land-based aircraft, which led to the development of longer-range carrier based aircraft. At the conclusion of WWII and the Korean War, the Navy began to develop long-range aircraft for carrier-based operations. The development of the atomic bomb was thought to change the prevention of war aspect that the Navy pursued, but the threat of the atomic bomb was not enough. The Navy was procuring aircraft based on atom bomb deterrence and delivery but attention was diverted from the need for conventional strike and fighter capability in carrier based aircraft.

Fighter aircraft were altered to include interception aircraft and long-range strike aircraft, such as the A-6 and F-4. During the Vietnam War, the United States realized a need to redevelop the fighter air wing for carrier based operations. The limited size of the carrier deck and the weight restrictions, due to the catapult system and supersonic speeds, have both limited the range of fighter and strike aircraft. Table 1 summarizes United States aircraft development from WWII through the 1990s.

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[5] Naval Historical Center, "U.S. Navy Active Ship Force Levels, 1945–1950," Department of the Navy, http://www.history.navy.mil/branches/org9-4.htm#1945 (accessed June 21, 2007).

Table 1. Aircraft Combat Radius from World War II (WWII) Through 1990s[6]

Period	Airframe	Distance
WW2	F6F TBF SB2C	400nm 400nm 400nm
Korea	AD-1 F9F	560nm 560nm
Vietnam	A-7 A-6 F-4	620nm 890nm 367nm
1980's	F-14 A-6	600nm 890nm
1990's	F/A-18C F-14 "Bombcat"	325nm 500nm

The proliferation of the anti-ship ballistic missile has created a new threat for the aircraft carrier. Ehrhard and Work state, "The offensive and defensive power of an aircraft carrier derives from its aircraft. Without its embarked air wing, a carrier is bereft of combat power and is little more than a large, defenseless target."[7] A new technology has reduced the effectiveness of an old capability. The aircraft carrier can no longer enter an effective combat radius to deliver time sensitive strikes without itself being vulnerable—the vulnerability of the carrier has surpassed the effectiveness. To enable the carrier with a capability of long-range strike, the air wing must once again be complemented with longer range strike aircraft. Without an air wing capable of conducting strike operations outside the known threat radius:

[6] Ehrhard and Work, *Range, Persistence, Stealth, and Networking,* 95.

[7] Ehrhard and Work, *Range, Persistence, Stealth, and Networking*, 45.

> The CSG is, remarkably, a construct that can operate effectively only in a permissive environment, or be committed to an anti-access environment only under the most extreme conditions when national interests compel leadership to risk what amounts to a significant percentage of the Navy's annual budget in a single engagement.[8]

Although the MSS outlines the six core capabilities of the Navy, the Navy is first and foremost about Sea Control. Sea Control is one of the six core capabilities, but the Navy could not perform a single one without Sea Control. In his book *The Next 100 Years*, George Friedman commented:

> [T]he single most important geopolitical fact in the world [is] the United States controls all of the world's oceans. No other power in history has been able to do this. And that control is not only the foundation of America's security but also the foundation of its ability to shape the international system...At the end of the day, maintaining its control of the world's oceans is the single most important goal for the United States geopolitically.[9]

To maintain Sea Control while meeting the current and future threats in the globalized world, the Navy must perform MSCE and work towards the 1000 ship Navy.[10] With the addition of brown and green water ships, coupled with forward deployment, the USN will reach out to partnership nations, develop lasting relationships and train the indigenous forces in Maritime Security.

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[8] Jon Hussman, "Buy Ford, Not Ferrari." *U.S. Naval Institute Proceedings* 135, no. 4, (April 2009): 2.

[9] George Friedman, *The Next 100 Years* (New York: Doubleday, 2009) 42–45.

[10] Michael G. Mullen, Testimony before the Senate Committee on Appropriations Subcommittee on Defense, 110th Cong., 2nd sess., 2007.

According to Mark Pratt, "During the QDR, the Navy developed a new fleet target of 313 ships, including a requirement for 11 aircraft carriers—all nuclear powered—and ten aircraft carrier wings."[11] Hussman has explained, "Step one is to abandon the idea of a Navy built around 11 or 12 carrier strike groups."[12] The capability gained from the addition of N-UCAS, specifically the 1500 nm unrefueled combat range, the 3500+ nm ferry range, and the 50-hour flight times, to the fleet will allow for alterations in the employment and deployment of air wings and aircraft carriers.[13] A comparison of N-UCAS to the current aircraft can be seen in Table 2.

Table 2. Future Air Wing Capabilities[14]

Aircraft Type	Max Speed	Flight Endurance	Payload Capacity	Approach Speed	Combat Radius	Ferry Range
N-UCAS	**500kts**	**50 hrs**	**4500lbs**	**125kts**	**1500nm**	**3500+nm**
JSF	**Mach1.6**	**10 hrs**	**8000lbs**	**125kts**	**590nm**	**700+nm**
Super Hornet	**Mach 1.6**	**10 hrs**	**8000lbs**	**125kts**	**945nm**	**1275nm**
Growler	**Mach 1.6**	**10 hrs**	**8000lbs**	**125kts**	**945nm**	**1275nm**
E-2D	**325kts**	**10 hrs**	**N/A**	**103kts**	**N/A**	**1541nm**

[11] Mark Pratt, "Kennedy Warship Makes Last Port Call in Boston," Associated Press (March 1, 2007), http://www.foxnews.com/story/0,2933,255655,00.html (accessed on March 21, 2007).

[12] Hussman, "Buy Ford, Not Ferrari."

[13]The ferry range is a range the aircraft can travel without a weapons load.

[14] “Aircraft,” *Jane's Fighting Ships*, March 2009; N-UCAS http://www.northropgrumman.com (accessed July 15, 2009).

Through the new employment/deployment model, it is possible that fewer aircraft carriers will be needed to deliver the same power projection capacity that is available today while increasing the fleet's capability to generate access. The reduction in aircraft carriers could free up funding to allow for the procurement of vessels and systems able to meet the capacity shortfall of performing MSCE.

C. FORCE STRUCTURE

Samuel Huntington suggested:

> A military service may be viewed as consisting of a strategic concept which defines the role of the service in national policy, public support which furnishes it with the resources to perform this role, and organizational structure which groups the resources so as to implement most effectively the strategic concept.[15]

Huntington saw the Navy’s purpose and role in carrying out national policy as utilizing its command of the sea to prevent war, maintain America's power along the littorals, and achieve supremacy on the land. The Navy’s role in carrying out national policy has not changed significantly since 1954. While Navy planners and budgeters have traditionally focused on the importance of winning the nation's wars, the Navy's role in preventing wars and disruptions to the global commons (including space and cyberspace) has made it indispensible to the security and prosperity of the nation. There is a compelling argument that "the Navy’s commitment to protecting the homeland and

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[15] Samuel P. Huntington, “National Policy and the Transoceanic Navy,” *U.S. Naval Institute Proceedings* 80, no. 5 (1954).

winning our Nation’s wars is matched by a corresponding commitment to preventing war.”[16] The ability of a nation to prevent war is inherent in the strategy set forth by the policy makers. The construction of the MSS outlines the need for the Navy to develop a means to operate in the ROMO (meeting capability challenges in access generation and capacity problems in MSCE), while constraining the budget.[17]

The MSS outlined the core capabilities that must be performed to accomplish the Navy's strategic goals. The geo-political atmosphere has changed in the past 50 years, exposing new threats in a new environment. To meet these goals, the Navy must operate in all environments (permissive, contested, and denied) while dealing with threats from irregular warfare to MCO's. The proliferation of technology has made it possible for adversaries to deny the United States in some domains.[18] These changing threats and environments have started attacking the ability of the traditional CSG/ESG force structure's capability to generate access and capacity to perform MSCE in the global commons. A new force structure, reorganizing the traditional unit of issue, concentrating on capability-based constructs will enable the Navy to operate effectively in the global commons, maintain global trade, defend the homeland, and remain capable of winning wars.

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[16] James T. Conway, Gary Roughhead, and Thad W. Allen, *A Cooperative Strategy for 21st Century Seapower* (Washington, D.C.: U.S. Department of the Navy and U.S. Coast Guard, 2007).

[17] Chas Richard et al., "Dispersed Distributed, and Disaggregated," (unpublished white paper, Chief of Naval Operations Strategic Studies Group, Newport, RI, 2009).

[18] The denial of the USN in all domains (cyber, space, air, land, sea, and undersea) would be a complete loss of sea control, with no way to regain access.

The future Navy will look different from today's Navy. The Global force lay down will be accomplished by distributing capabilities that are tailored for the threat and environment in the area of operation. Capability matching will replace the current distribution method of CSG/ESG distribution. Today the CSG/ESG can disperse geographically, but it is limited to remain within defensive range of the carrier or concentrate to deliver combat credible force. The ability of a future force to aggregate combat credible force through means other than geographic (cyber or communications) will enable further dispersal of the force. The proliferation of unmanned systems will allow the future force to separate sensors, deciders, and effectors. By disaggregating the fleet and coupling it with network centric warfare, the fleet can accomplish FORCEnet.[19]

To meet the goals of the MSS, the future Navy must be globally distributed and geographically dispersed. By altering the unit of issue away from the CSG/ESG construct, the global force lay down can be constructed around capabilities therefore tailoring the fleet to the threats and environments in the area of operation. The dispersion of the fleet, while allowing the aggregation of combat credible power to occur through communications, cyber, and physical means, can achieve control of the seas while meeting the goals of the MSS.

[19] FORCEnet is the operational construct and architectural framework for Naval Warfare in the Information Age.

1. Access Generation—From the MSS coupled with Power Projection

The USN has not been denied in a domain in recent history, but the proliferation of anti-ship ballistic missiles is posing a threat to the carrier fleet. The carrier has a limited ability for self protection and the large deck allows for relatively easy targeting in the open ocean at ranges that reduce the ability for the carrier to deliver the embarked air wing. To remain effective, the Navy must disperse the fleet, increase the effective range of the air wing, and regain access to the surface domain by using the subsurface and air domains.

2. Power Projection—From the MSS coupled with Access Generation

The ability to accomplish power projection over land is a task shared by all the departments in the military. One of the means of power projection is the delivery of time sensitive, eyes-on-target strike by the embarked air wing on the carrier. Due to the anti-ship ballistic missile threat, the carrier fleet cannot approach the effective combat radius in a MCO for the air wing and must concentrate the CSG to increase defense of the carrier—limiting the ability to deliver combat credible force. By investing in longer range carrier based aircraft, the Navy can once again deliver the power projection necessary in a MCO against a peer/near peer adversary.

3. Maritime Security and Cooperative Engagement (MSCE)—Coupling Forward Deployed, Maintenance of Security at Sea, and Building Relationships

The traditional CSG/ESG is able to perform MSCE operations but has limited capacity. Increasing life-cycle costs do not properly match the capabilities of the CSG/ESG with the MSCE operations the force and global commons are threatened with today and will be in the future.[20] The advancement in unmanned vehicle technology has created a means for smaller maritime crafts, such as the Littoral Combat Ship (LCS) and the Joint High Speed Vessel (HSV), to increase their capabilities for Intelligence, Surveillance, and Reconnaissance (ISR) and self-protection. By increasing the capacity of the fleet to perform MSCE, with ships that are more suited to the operations, the Navy will be able to match capabilities with the operations while increasing the cooperative engagement. The Navy can aid in partnership nations' development to conduct maritime security and reach the goal of the 1000-ship Navy. The Secretary of Defense stated in a speech at the Army War College, “The black and white distinction between irregular war and conventional war is an outdated model.”[21]

D. THE WAY FORWARD

The Navy must be enabled to perform Access Generation, Power Projection, and MSCE. The range of the embarked air wing will render the carrier fleet incapable of achieving

[20] Expected outcome of the QDR.

[21] Robert Gates, speech, (presented at the Army War College, Carlise, PA, 15 April 2009).

the above task without support from other assets.[22] The addition of N-UCAS to the carrier fleet will enable the air wing with the capability of access generation in the air to regain access to the surface domain. The capabilities of N-UCAS outlined in Table 2 will enable the carrier fleet to employ and deploy the air wing differently in the future.

This thesis will analyze whether the new structure will enable the Navy to achieve the benefits of the power projection force today in the future while reducing the carrier fleet. A reduction in the carrier fleet could make funding available to increase the Navy's capacity to perform MSCE. The capabilities that N-UCAS can bring to the embarked air wing will be analyzed to determine if the addition of N-UCAS can increase the capacity inherent in the carrier to perform the mission sets that the air wing perform. N-UCAS integration into the strike/fighter squadron will be the only estimated portion of the air wing due to the assumption that the capabilities of the demonstrator model will be the same as the production model. Cost estimations will accompany a cost analysis to determine whether the addition of N-UCAS can reduce the Navy's budget allowing for the funding of MSCE crafts.

[22] The Air Force, Army, and Marine Corps are all part of the power projection force.

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II. CARRIER AIR WING OF THE FUTURE: EVOLUTIONARY VERSES REVOLUTIONARY

> As the Navy's major power projection element, the aircraft carrier and its expeditionary air wing are critical to battlefield success, but with pressure to cut defense budgets and the declining global threat, the USN is rethinking the size and scope of the carrier air wing of the 21st Century.[23]

A. INTRODUCTION

The future of the aircraft carrier is dependent on the composition of the air wing. As the threats and environments change, the air wing must be able to meet the growing expeditionary requirements while projecting power from beyond the surface denied area. The employment and deployment of the carrier air wings can be accomplished in two ways: Revolutionary and Evolutionary. The Evolutionary carrier air wing will be composed of aircraft that are a continuum of the current structure that the Program Objective Memorandum 2010 (POM10) has outlined. With the proliferation of Unmanned Vehicles (UV's), it will become necessary for the center of the USN's power projection to develop organic Unmanned Aerial Vehicle (UAV) capability and capacity. The Revolutionary air wing will examine three steps of N-UCAS integration to increase the capabilities and capacities of the aircraft carrier.

[23] Barbera Starr, "U.S. Navy Aviation Multi-Role is the Key to Smaller Air Wings," *Jane's Defense Weekly* 19, no. 14 (2003): 28.

The current air wing is composed of:[24]

- Two strike fighter squadrons of Hornets (10-12 aircraft per squadron)
- Two strike fighter squadrons of Super Hornets (10-12 aircraft per squadron)
- One Electronic Attack squadron of Prowlers (4 aircraft)
- One Carrier Airborne Early Warning squadron of EA-2C(3 aircraft)

(For the purposes of this study the Fleet Logistics squadron and Helicopter squadron will not be examined.)

B. EVOLUTIONARY

The future air wing will look similar to the air wing today composed of:

- Two strike fighter squadrons of Joint Strike Fighters (JSF) (10-12 aircraft per squadron)
- Two strike fighter squadrons of Super Hornets (10-12 aircraft per squadron)[25]
- One Electronic Attack squadron of Growlers (5 aircraft)
- One Carrier Airborne Early Warning squadron of EA-2D's (5 aircraft)

The capabilities and missions of the future air wing are outlined in Tables 2, 3, and 4.

[24] Lambeth, *Air Power at the Dawn of A New Century*.

[25] The Super Hornet Squadrons will be systematically replaced with new aircraft, most likely JSF, as they come to the end of their useful life.

Table 3. Mission Sets for Future Strike Fighter Aircraft[26]

Mission / Aircraft Type	Fighter Escort	Fleet Air Defense	Strike	Interdiction	Close in Air Support	Reconnaissance
N-UCAS			X		X	X
JSF	X	X	X	X	X	X
Super Hornet	X	X	X	X	X	X

Table 4. Mission Sets for Future Electronic Attack (EA) and Airborne Early Warning (AEW) Aircraft[27]

Mission / Aircraft Type	AEW	CC	Surface Surveillance	Strike and Interdiction Control	SAR	Comms Relay	EW
N-UCAS	X		X			X	X
E-2D	X	X	X	X	X	X	X
Growler							X

1. Strike Fighters

The addition of F/A-18 E/F brings greater endurance and distance to the fleet increasing the carriers' capability to accomplish air superiority and long-range strike from the aircraft carrier. The F/A-18 E/F also brings the ability to act as an air tanker, thus eliminating the need for the S-3 on the carrier. The addition of the Joint Strike Fighter (JSF) to the carrier air wing will give greater stealth capabilities and upgrade the legacy technology present in the F/A-18. Although its capabilities enhance the air wing, the JSF's combat radius

[26] "Aircraft," *Jane's Fighting Ships*.

[27] Ibid.

is shorter than the F/A-18, thus reducing the capability to perform long distance strikes.

2. Electronic Attack

Since the F/A-18 aircraft design is proven and is capable, the Growler is made from the same airframe. The Growler will enable the Electronic Attack (EA) squadron to have self-defense capabilities and eliminate the need for fighter escorts while increasing the EA combat radius and enable aerial refueling. The Growler will be able to accompany the Strike Fighter Squadrons in all missions because it can match the supersonic speed of the F/A-18 E/F.

3. Airborne Early Warning

The E-2D is an upgrade to the E-2C. The upgrade will include new radar systems, infrared search and track, modular communications equipment, multi-sensor and tactical glass cockpit, and flat-panel primary flight displays. The aircraft will be able to increase command and control functions, air and sea surveillance, and communications functions for the tactical commander.

C. REVOLUTIONARY

In *Skunk Works*, Rich and Janos describe a system:

> At the Heart of the system were two powerful computers that detailed every aspect of a mission, upgraded with the latest satellite-acquired intelligence so that the plan routed a pilot around most dangerous enemy radar and missile locations. When the cassette was loaded into the airplane's system, it permitted "hands-off" flying though all turning points, altitude changes, and airspeed adjustments. Incredibly,

> the computer program actually turned the fighter at certain angles to maximize its stealthiness to the ground at dangerous moments during the mission, when it would be in range of enemy missiles, and got the pilot over his target after a thousand-mile trip with split section precision. Once over the target, a pilot could override the computers, take control, and guide his two bombs to target by infrared video imagery. Otherwise, our auto piloted computer was programmed even to drop his bombs for him.[28]

At the close of the Cold War, the technology allowed for a stealth bomber to be capable of unmanned operation, but the systems left the man in the loop for delivering lethal effects. The next step in the evolution of unmanned systems was to place the control on a shore base as was used in the War on Terrorism at the beginning of the twenty-first century. The addition of N-UCAS to the carrier air wing is a logical direction for the Navy to take. The aircraft will be capable of performing the mission sets outlined in Tables 3 and 4, with the capabilities in Table 2.

As seen in the comparison to the manned aircraft, N-UCAS is not capable of operating at super-sonic speeds, and due to the orientation and decision limitations without the human in the aircraft, the N-UCAS cannot operate as a Command and Control element. However, it could be used to feed information to shore or ship based command and control units. The capabilities of the platform can enhance the move towards Maritime Operations Centers (MOC) and increase the disaggregation and dispersion of the fleet.

[28] Ben R. Rich and Leo Janos, *Skunk Works* (Little Brown and Company, New York, 1994), 95.

The following three models integrate N-UCAS into the carrier air wing. First, N-UCAS will be used to augment the Strike Fighter Squadrons. Second, N-UCAS will replace the Electronic Warfare (EW) portion of the air wing, and the N-UCAS will replace the E-2D last. The models are developed to replace aircraft as technology progresses and current aircrafts are at the end of their useful life. Assumptions for the analysis are outlined in Appendix A.

1. N-UCAS Integration into the Strike Fighter Squadrons

The addition of N-UCAS to the Strike Fighter squadrons will enhance the capabilities to perform long-range, persistent strike and Intelligence, Surveillance, and Reconnaissance (ISR), while increasing the capacity to perform all mission sets outlined in Table 3. The F/A-18 has replaced the carrier-based aerial refueling planes the S-3. There has not been any replacement to the deck space—the S-3 was a large plane that took up a lot of deck space. Six N-UCAS can be added to the carrier air wing in place of the S-3 to allow the manned strike fighters to train and conduct continuing operations at sea with N-UCAS. Although only six aircraft, the extensive unrefueled ferry range of the N-UCAS will allow the carrier to be complemented with an additional 12 aircraft within eight hours from most U.S. land bases.[29] This will give the carrier an additional 18 assets to perform strike and ISR.

[29] A new flight deck operations model would need to be developed to accommodate continuous sortie generation with the new aircraft, but the thesis will not model new flight deck operations. The aircraft carrier can accommodate the aircraft.

The JSF and Super Hornet are both capable of supersonic speed, and the human in the loop allows for dynamic environment updating for faster reaction time. The technology for dynamic environment updating to the onboard computer systems is not yet available to allow the N-UCAS to perform as well as the JSF and Super Hornet in air-to-air combat.[30] Once access has been generated and the power projection forces roll in, close-in air support can be accomplished by the manned or unmanned aircraft.

The thesis is not intended to argue the legal, ethical, or trust issues involved with allowing unmanned aircraft to provide ground support to the troops in area. The thesis only examines the ability to complement the air wing with the use of N-UCAS in both strike and ISR missions.

2. N-UCAS Integration into the Electronic Attack (EA) Squadron

The Growler will be the manned aircraft responsible for EA in the fleet. The Growler has several capabilities that the N-UCAS does not. The Growler has the same airframe as the Super Hornet and can travel at supersonic speeds, aerial refuel, and provide self-protections, but the basic missions accomplished by the aircraft can be accomplished by N-UCAS. This thesis will examine the alteration of the EA squadron to include three N-UCAS with two Growlers.

[30] The ability for an unmanned system to respond is dependent on the sensor grid that the system is networked with. A capable, integrated infrastructure for sensing would be able to deliver real-time information to unmanned systems enabling operation in a dynamic environment.

3. N-UCAS Integration into the Airborne Early Warning Squadron (AEW)

The E-2D is not only able to accomplish the missions that N-UCAS can as outlined in Table 4, but it can provide overall command and control functions for the air wing. The replacement of the E-2D with N-UCAS can be accomplished by giving N-UCAS all the sensing and integrating that is in the E-2D. This will allow the command and control functions to be accomplished from any platform that is communicating with the N-UCAS. The commander of all operations can be on the carrier, destroyer, cruiser, or even a submarine.

Satellite communications are available in the permissive environments; but once the environment becomes contested or denied, Line of Sight (LOS) communications are necessary. The addition of laser communications to the fleet will add redundancy to communications and gives the Fleet Commander the option to place the operational commander for the air forces on any platform. The replacement of five E-2Ds with five N-UCAS will enable the fleet to disaggregate the sensor from the deciders and from the effectors. This will allow the N-UCAS to queue ballistic or cruise missiles from other assets, such as submarines or destroyers. This thesis analyzes the inclusion of N-UCAS into the AEW squadron.

III. CAPABILITY AND CAPACITY COMPARISON

> *More broadly, the ancients understood technological progress: For it is a rule that, just as in crafts, the new always prevails.*[31]

A. INTRODUCTION

The integration of N-UCAS into the future carrier air wing must be analyzed on both the capabilities and capacities that are enhanced and lost due to the integration. Both the capabilities and capacities brought to the fleet from N-UCAS are dependent on the 50-hour flight time and internal payload of N-UCAS. The assumptions and calculations used in the analysis are in Appendices A and B respectively.

B. STRIKE FIGHTER SQUADRONS

The evolutionary strike fighter squadrons can perform the mission sets in Table 3. The addition of N-UCAS to the fleet will increase the capacity and capability in both the ISR and Strike missions. The model for the Revolutionary air wing will have the same capability and capacity with the JSFs and Super Hornets. The six N-UCAS that will be embarked on the carrier will enable integrated manned and unmanned aircraft training while increasing the organic UV capacity and capability of the carrier.

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[31] J.E. Lendon, *Soldiers and Ghosts: A History of Battle in Classic Antiquity* (New Haven: Yale University Press, 2005), 10.

1. Intelligence, Surveillance, and Reconnaissance (ISR)

Manned aircraft ISR capacity is limited due to flight time restrictions on manned aircraft and due to the other mission sets that the aircraft needs to accomplish. Figure 1 shows the comparison of the N-UCAS time on station to the manned aircraft.

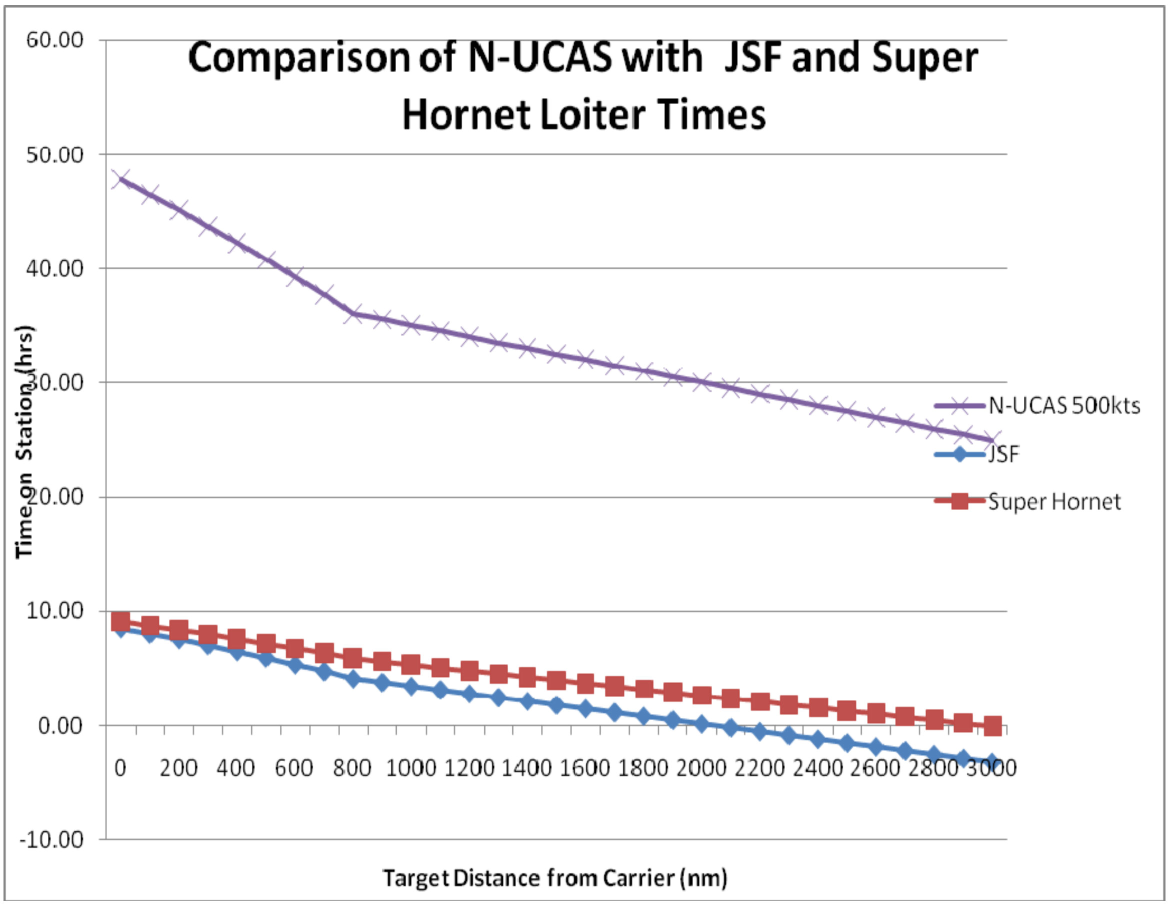

Figure 1. N-UCAS Time on Station Compared to Manned Aircraft

The comparison of the aircraft for ISR is accomplished by comparing the maximum time on station for a 50-hour flight of N-UCAS with a 10-hour flight of manned aircraft. As the distance from the carrier increases, the benefits

for integration of N-UCAS into the carrier air wing become apparent. Figure 2 illustrates the increase in the capacity to perform ISR, in terms of time on station with sensors, with the six embarked N-UCAS on the air wing.

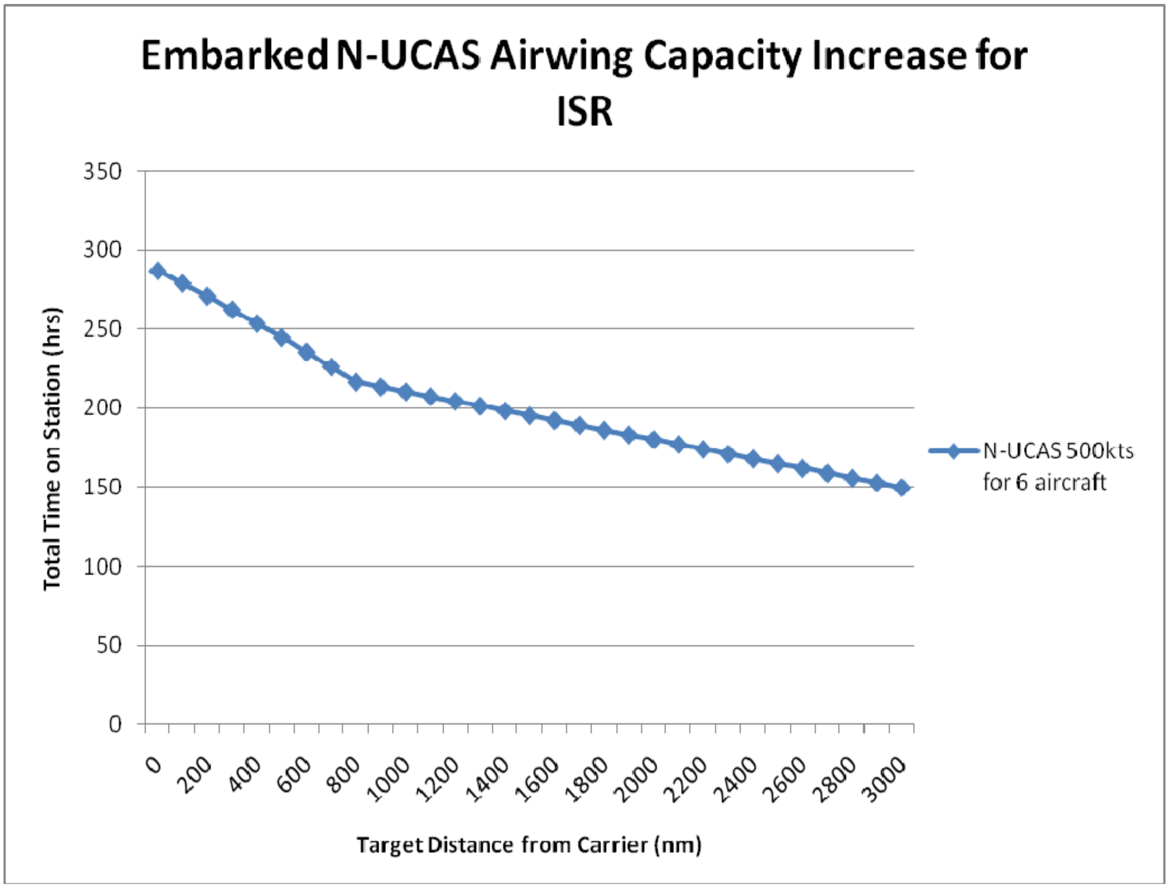

Figure 2. Additional ISR Capacity Gained from 6 Embarked N-UCAS

2. Strike

N-UCAS brings a new capability to generate access in the surface-denied domain that has grown due to the proliferation of anti-ship ballistic missiles. The 1500nm unrefueled combat radius of N-UCAS allows the air wing to deliver a time-critical precision strike in the surface

denied domain to regain access for the carrier. A typical alpha strike consists of eight to 10 strike fighters used to deliver approximately 8000lbs of payload each. The total complement will be 64000–80000lbs of payload per sortie.[32] The additional six embarked N-UCAS can be complemented by 12 N-UCAS from a land base due to the unrefueled ferry range of 3500+nm. The total of 18 additional strike aircraft can deliver 4500lbs of payload each for a total of 81000lbs of payload. This is roughly increasing the capacity of the carrier by one additional strike air wing. It is outside the scope of this thesis to analyze a new carrier flight deck operations model that will be needed for extended strike missions with N-UCAS.

The JSF will have new stealth technology to increase the capability of the air wing. The stealth of both the JSF and Super Hornet are reduced when they are fully loaded out, but the N-UCAS has internal payload capacity allowing stealth to be retained. The future strike air wings will still require AEW capacity; but self-protection is organic to the Growler, and no fighter escort is required.

C. ELECTRONIC WARFARE SQUADRON

Lambeth explained the need to replace the Prowler:

> The Prowler is long overdue to be replaced. It is not aerodynamically compatible with the current-generation strike aircraft. Not only is it g-limited, it cannot keep up with a strike package of F/A-18s. These performance shortcomings have forced EA-6B aircrews to devise

[32] "Aircraft," *Jane's Fighting Ships*.

> innovative tactics, techniques, and procedures to operate effectively with strike fighters.[33]

The addition of five Growlers to the air wing will increase the capability to perform strike operations without need for a fighter escort or limitations to speeds and g-limits. Altering the air wing by three Growlers, while adding three N-UCAS, will reduce the ability for the air wing to sortie at super-sonic speeds but will increase the capacity to perform persistent EW. The capabilities of the demonstrator N-UCAS do not include parameters for EW. To add that capability, N-UCAS will require more funding for RDT&E, testing, and demonstration. Figure 1 compares the time on station of the N-UCAS to the Super Hornet and the Growler, a variant of the Super Hornet, which is also limited to 10-hour flight times. Figure 3 compares the total air wing EW persistence.

[33] Lambeth, *Air Power at the Dawn of a New Century,* 82-83.

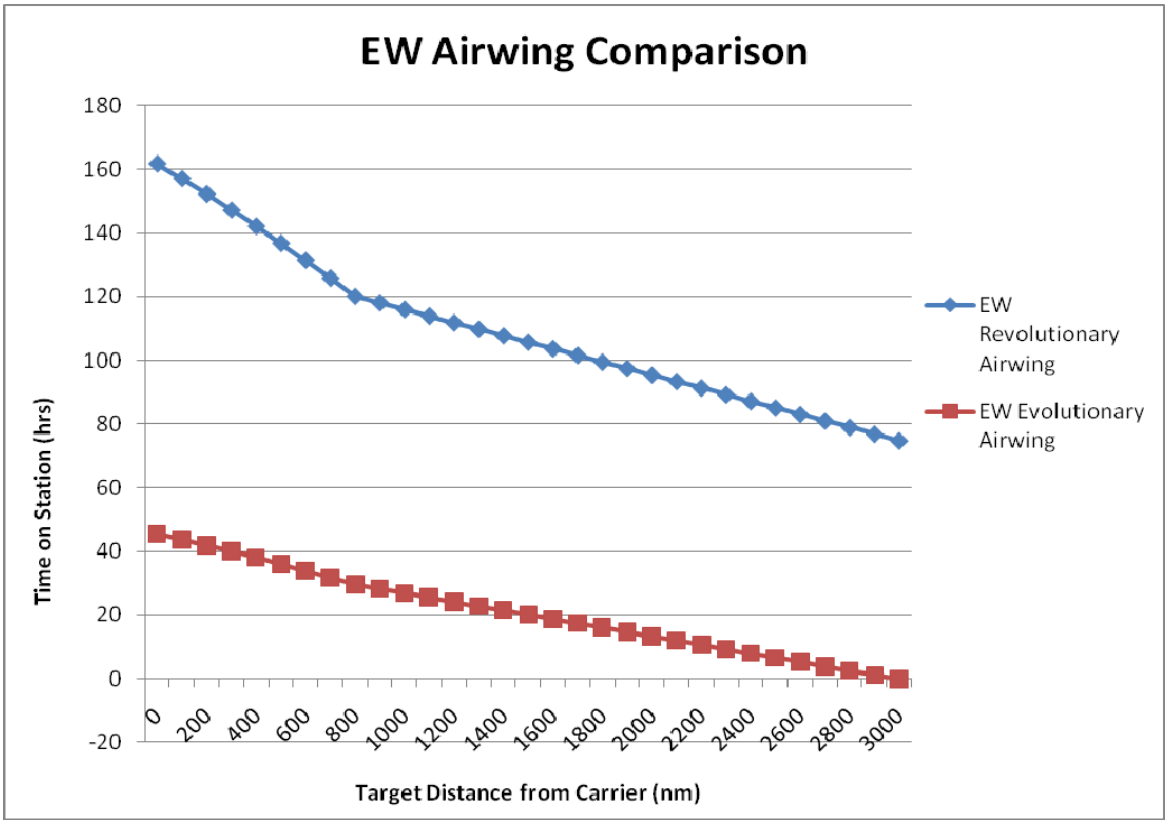

Figure 3. Total Air Wing EW Persistence Comparison Between Air Wings

D. AIRBORNE EARLY WARNING SQUADRON

The five E-2Ds in the air wing will increase the capability of the air wing with upgraded technology. By changing out all five E-2D's with N-UCAS, assuming comparable capabilities, the N-UCAS will increase the capacity of the air wing to perform persistent AEW but will limit the command and control functions of the aircraft. Although the command and control functions cannot be accomplished by the N-UCAS, the command and control functions can be done from any platform that is able to communicate with the aircraft. The time on station of the N-UCAS is increased from that of the E-2D, as per Figure 4.

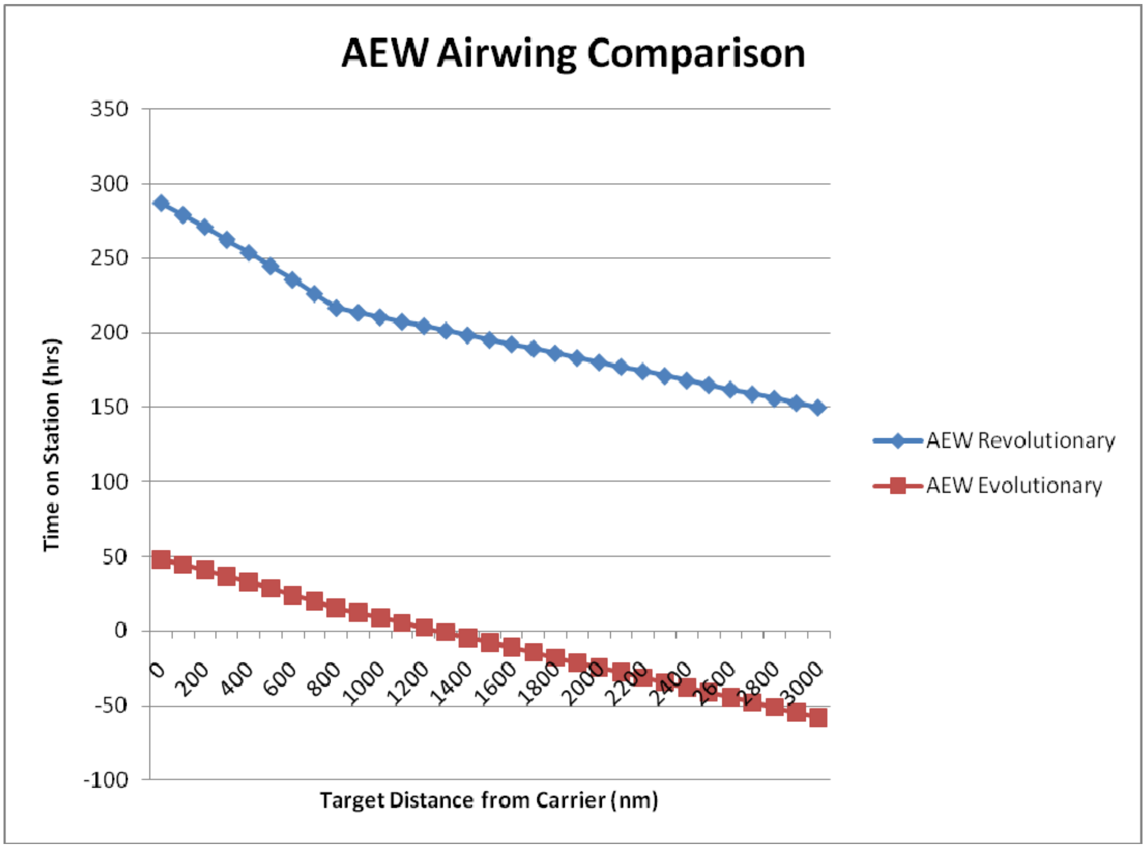

Figure 4. Total Air Wing AEW Persistence Comparison Between Air Wings

With the Air Commander on a separate platform, the N-UCAS can queue (request follow on missile launches) the commander to launch subsequent ballistic or cruise missiles to targets identified by the N-UCAS. This function will give the commander greater flexibility in the employment of lethal force. The capabilities of the demonstrator N-UCAS do not include parameters for AEW. That capability will require more funding for RDT&E, testing, and demonstration.

E. CONCLUSION

The capacities and capabilities of the air wing are all enhanced due to the addition of N-UCAS into the future

air wing. The limiting capacity improvement is in the area of payload capacity—since the additional N-UCAS will increase the capacity to deliver one additional air wing's worth of strike capacity. This means that the revolutionary air wing will make the future carrier air wing the equivalent of 1.5 times the capacity of today's air wing. Therefore, nine aircraft carriers will give the fleet the same capacity and capability for strike as 13 and one-half carriers without N-UCAS. Although the capacity of the air wing can be increased with the additional N-UCAS in AEW and EW, this thesis analyzes the limiting factors of increasing the strike and ISR abilities of the embarked air wing.

IV. N-UCAS LIFE CYCLE COST (LCC) ESTIMATION

A. INTRODUCTION

Approximately one third of what the Navy spends in procurement, research, and development on large acquisitions is for carriers and their associated air wings—precisely those items that N-UCAS can replace at significantly lower costs. In fact, 33 percent of what the Navy spends for Selected Acquisition Reports (SAR) reportable programs is for carriers and the air wings. Figure 5 displays the breakdown of 2007 SAR resources.[34]

[34] The congressional Research Service determined in September 2009 that 2456 JSF were going to be procured with 680 for the Navy and Marine Corps. Since the JSF is in the DoD SAR (the SAR is broken down into four categories DoD, Navy, Army, and Air Force) 28 percent of JSF funding was included in the Navy funding.

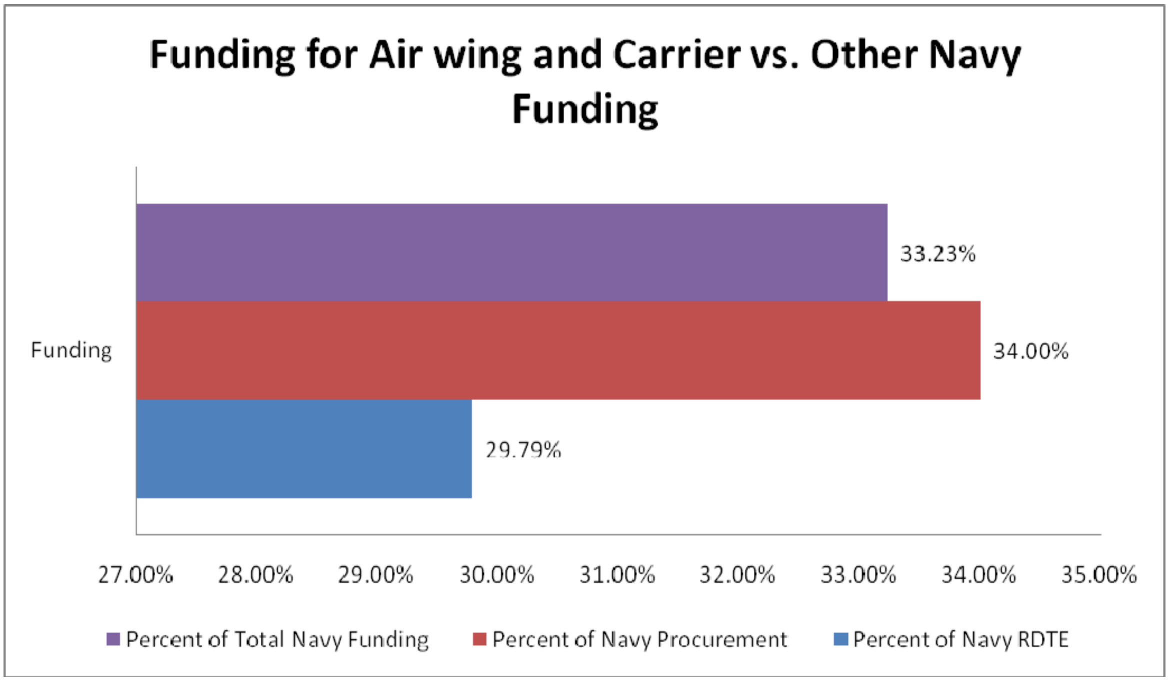

Figure 5. Breakdown of SAR by Percentage of Total SAR Navy Investment[35]

B. SCHEDULE

The production and integration of unmanned systems is relatively new with few historical precedents. We needed a schedule for LCC estimation, but the literature illustrated contradictory schedules. A schedule was presumed that meshed historical data with RDT&E funding. Figure 6 illustrates a Gantt chart similar to the one used in the production of Global Hawk. The Gantt chart has been modified for N-UCAS with the assumption that a carrier landing will be accomplished as scheduled in 2011. If there are no alterations to the demonstrator model, the

[35] U.S. Department of Defense, "Office of the Secretary of Defense," U.S. Department of Defense, http://www.defenselink.mil/osd/ (accessed online August 2009).

timeline through production will be similar to the Global Hawk, and full production can be accomplished by approximately 2020.

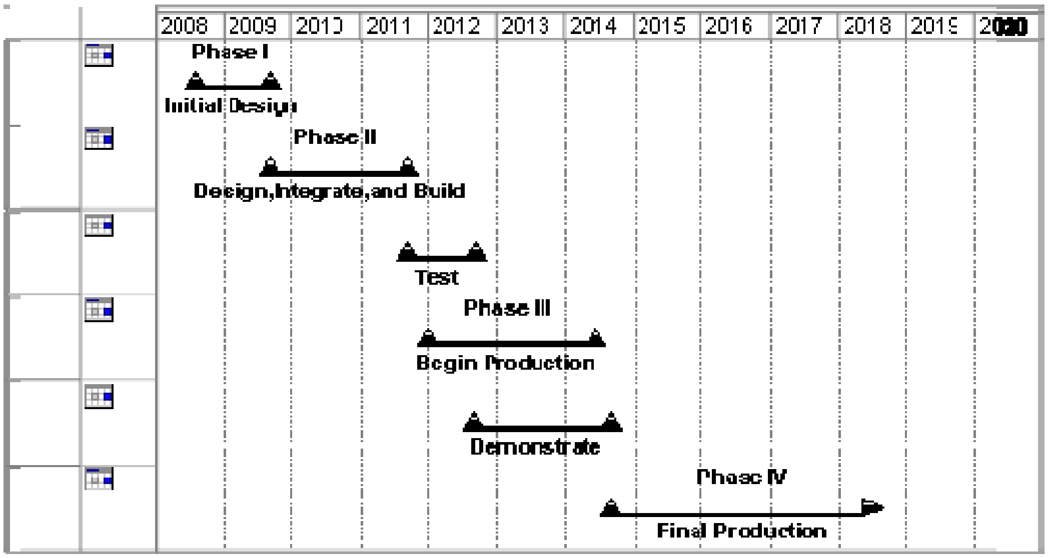

Figure 6. Assumed Schedule for N-UCAS production[36]

C. COST ESTIMATION METHODOLOGY

We developed a LCC estimate for N-UCAS, including Research and Development, Procurement, and O&S costs. A summary of our estimating approaches is in Table 5, and details of these estimates are in the following paragraphs. All estimates will eventually be converted to FY10$, using inflation indices from the Naval Center for Cost Analysis (NCCA).

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[36] Jeffrey Drezner and Robert Leonard, *Global Hawk and DarkStar* (Santa Monica, CA: RAND, 2002).

Table 5. Summary of Work Breakdown Structure with Basis for Evaluation[37]

Work Breakdown Structure	FY10$M	Basis for Evaluation
Total RDT&E Costs	1468	RDT&E 0604402N, UNMANNED COMBAT AIR VEHICLE (UCAV) ADV CP/PROTO DEV [38]
Total Production Costs	5013	DASA-CE for T1, Standard Cost Factor Handbook, Learning Curve Theory
Total O&S Costs	16224	Analogy to F/A-18 E/F, Ratios in Table 14

1. Research, Development, Test, and Evaluation

We used FY09 RDT&E Budget Data, available at http://www.defenselink.mil/comptroller/defbudget/fy2009/index.html, with the results listed in Table 6. These data are in then-year millions of dollars and were converted to FY10$M using NCCA inflation indices in Table 7. The RDT&E of the N-UCAS demonstrator budget covers FY07-FY13, when carrier implementation and testing is assumed to be completed.

[37] It has been noted that MILCON can be integrated into the LCC estimation, but this thesis did not include an estimation of MILCON.

[38] Office of Under Secretary of Defense (Comptroller), “Defense Budget Materials.”

Table 6. RDT&E Funding for N-UCAS[39]

EXHIBIT R-2, RDT&E Budget Item Justification					DATE: February 2008		
APPROPRIATION/BUDGET ACTIVITY RESEARCH DEVELOPMENT TEST & EVALUATION, NAVY / BA-7					R-1 ITEM NOMENCLATURE 0604402N, UNMANNED COMBAT AIR VEHICLE (UCAV) ADV CP/PROTO DEV		
COST ($ in Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total PE Cost	97.1	158.2	275.8	315.8	271.9	222.0	170.4
3178 UNMANNED COMBAT AIR SYSTEM CV-DEMO (UCAS-D)	97.1	158.2	268.5	269.5	205.1	133.4	85.5
3191 UCAS TECHNOLOGY MATURATION			7.2	46.2	66.7	88.5	84.8

[39] Office of Under Secretary of Defense (Comptroller), “Defense Budget Materials.”

Table 7. RDT&E Totals for N-UCAS by Year in Millions of FY10$

COST ($ in Millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Total RDT&E Cost	97.1	158.2	275.8	315.8	271.9	222.0	170.4
Multiplier	1.02	1.00	0.99	0.98	0.96	0.94	0.93
Total RDT&E Costs FY10$ in millions	98.9	158.8	273.4	308.4	261.1	209.5	157.9

2. Production

We developed the Work Breakdown Structure (WBS) and Basis of Estimates (BOE) for the production phase of N-UCAS that is in Table 8.

Table 8. Work Breakdown Structure and Basis for Estimation for RDT&E[40]

Work Breakdown Structure	**Basis for Evaluation**
Manufacturing	Learning Curve Theory and DASA-CE Study
Non-Recurring	Standard Cost Factors Handbook (3.9%)
Total Support	Standard Cost Factors Handbook (13.8%)
Airborne Support Equipment	Standard Cost Factors Handbook (4.0%)
Engine Support Equipment	Standard Cost Factors Handbook (0.7%)
Avionic Support Equipment	Standard Cost Factors Handbook (1.7%)
Training Equipment	Standard Cost Factors Handbook (3.0%)
Publication	Standard Cost Factors Handbook (1.7%)
Factory Parts	Standard Cost Factors Handbook (0.3%)
Miscellaneous	Standard Cost Factors Handbook (2.3%)
Intial Spares	Standard Cost Factors Handbook (9.8%)

[40] Noreen Bryan, "Standard Cost Factors Handbook" (Washington, D.C.: Naval Air Systems Command, Naval Center for Cost Analysis, 1992).

3. Manufacturing

We modeled the unit production with a notional 95 percent learning curve. We used the following nominal production schedule in Table 9, which we developed in order to provide a gradual integration of N-UCAS with current manned systems.

Table 9. N-UCAS Quantities in Production Lots

Lot 1	**12**
Lot 2	**18**
Lot 3	**24**
Lot 4	**18**
Lot 5	**18**
Lot 6	**18**
Lot 7	**18**
Lot 8	**18**
Lot 9	**18**

The cost for each lot was determined with the following equation using unit theory:[41]

$$CT_{F,L} = \frac{AL^{b+1}}{b+1} - \frac{A(F-1)^{b+1}}{b+1}$$

CT = Cost of Total Lot

A = Cost of First Production Model (T1)

L = Number of Last Model in Lot

F = Number of First Model in Lot

b = ln(0.95)/ln(2) = -0.074

We used the analysis completed by the Deputy Assistant Secretary of Army Cost Estimating (DASA-CE) on UAV's. Figure 7 includes the UAV's used in the analysis and the data available for each of the UAV's.

[41]Dan Nussbaum, "Cost Estimation Methodology" (lecture, Naval Postgraduate School Monterey, CA, summer 2009).

	Platform	Contractor Cost Rept.	Contractor Acct Rec's	Historical Budget	Contract	Program Documents	Proposal	Cost Study	Open Sources	Estimates
Primary	Dragon Eye		X		X	X			X	X
	Fire Scout		X			X			X	
	Global Hawk	X				X		X	X	X
	Hunter	X				X			X	X
	Outrider	X	X			X			X	X
	Pioneer			X	X		X		X	
	Predator	X		X		X			X	
	Pointer								X	
	Shadow 200	X		X		X				X
Secondary	Camcopter 5.1								X	
	Compass Cope	X	X			X				
	Desert Hawk					X			X	
	Eagle Eye	X			X	X				X
	SkyEye			X	X			X		
	Ugglan Owl								X	
Other	Amber I			X	X			X	X	
	Aquilla	X						X	X	X
	Cypher II				X				X	
	MR UAV	X			X	X				X
	Vigilante								X	X

Figure 7. UAVs Used to Produce the Model for Estimation of the First Production Model by DASACE[42]

The performance-based model was used to determine the cost, in FY03$K, of the First Production Model (T1) for N-UCAS. Figure 8 is the model used to estimate T1 for N-UCAS with the supporting statistics.

[42] John Horak, *Cost Performance Estimating Relationships (CPERs) for UAV Payloads* (presentation at Department of Defense Cost and Software, Virginia, 2007).

UAV T1 (FY03$K) = 118.75 * (Endurance*Payload_Wt.)$^{0.587}$ * $e^{-0.010(FF\_Year-1900)}$ * $e^{-0.921(Prod\ 1/0)}$

T Statistics: (7.8) (40.2) (-1.6) (-10.8)
Statistics adjR^2 = 99.4% s = 0.149 (+16.1%, -13.9%)
(13 Data Points) (9 Degrees of Freedom)
Where: UAV T1 = Theoretical first unit cost of UAV air vehicle hardware normalized for learning (95% slope) and rate (95% slope), via unit theory.
In FY03 $K.
Endurance = UAV air vehicle endurance in flight hours
Payload_Wt. = Weight of total payload in pounds. Total payload includes all equipment other than the equipment that is necessary to fly and excludes fuel and weapons.
FF_Year = Year of first flight Prod 1/0 = 1 if air vehicle is a production unit. = 0 if air vehicle is a development or demonstration unit.

Figure 8. Model for Cost Estimation and Statistical Data[43]

Figure 9 indicates the accuracy of the best fit model for the aircraft used in determination of N-UCAS cost estimations. The graph plots the estimated costs (FY03$K) of the first production models, versus the actual costs (FY03$K) of the first production models, for the UAVs in the underlying data set.

[43] Horak, "Cost Performance Estimating Relationships."

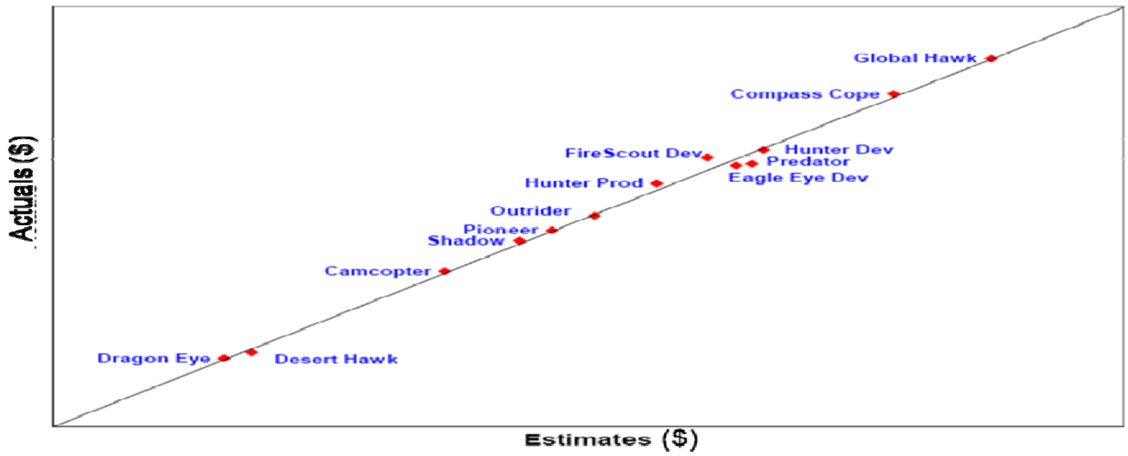

Figure 9. Best Fit Model for UAV's Used by DASA-CE[44]

The following data (Table 10) were used in the determination of T1:

Table 10. Data Used in Determination of T1[45]

Endurance in flight hours	**50**
Payload Weight	**8000**
Year of First Flight	**2011**
Prod 1/0 1 if production unit 0 if demonstration unit	**1**

Based on the model, T1 was estimated and normalized to FY10$ using the inflation indices published by the Navy Center for Cost Estimations to be $30.3M (FY10).

The T1 calculated above of $30.3M (FY10) will be the A in the production model equation:

Cost = 30.3 *X^b, where the slope is assumed to be 95% for N-UCAS; therefore b = ln(0.95)/ln(2) = -0.074, and X is the Quantity produced

44 Horak, "Cost Performance Estimating Relationships"

45 Greg Goebel, "16.0 UAVS," In the Public Domain (January 1, 2009), http://www.vectorsite.net/twuav_16.html (accessed August 2009); "X-47 Pegasus Naval Unmanned Combat Air Vehicle (UCAV-N), USA" Air Force Technology.com, http://www.airforce-technology.com/projects/x47/ (accessed August 2009).

The equation used in individual units (which will then be aggregated into estimated costs of production lots) is:

$$\textbf{Cost (FY10\$M)} = 30.3\ X^{-0.074}$$

The cost of each lot and the subsequent total cost normalized to FY10$K using inflation indices from the NCCA is in Table 11.

Table 11. Cost of Each Lot in FY10$M

Lot	Lot Cost (FY10$M)
Lot 1	819.8
Lot 2	1095.3
Lot 3	1385.3
Lot 4	1007.4
Lot 5	988.8
Lot 6	974.1
Lot 7	962.1
Lot 8	952.0
Lot 9	943.2
Total (FY10$M)	9128.0

D. OTHER PRODUCTION COSTS

Other production costs were determined by multiplying the manufacturing costs by a cost factor from Table 8. The Standard Cost Factors Handbook indicates that typically 72.5 percent of production costs are attributed to manufacturing while 27.5 percent are attributed to other production costs. The ratio of these two numbers shows that typically 38 percent of the manufacturing costs are analogous to the other costs.

The summary for the production costs for N-UCAS are summarized in Table 12.

Table 12. Production Totals for N-UCAS by Year in Millions of FY10$

COST ($ in Millions)	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
FY10$ in millions for manufacturing	326.4	436.1	551.5	401.1	393.6	387.8	383.0	379.0	375.5
Other Production Costs in FY10$ in millions	123.8	165.4	209.2	152.1	149.3	147.1	145.3	143.8	142.4
Total Production Costs in FY10$ in millions	450.2	601.5	760.7	553.2	543.0	534.9	528.3	522.8	517.9

1. Operations and Support (O&S)

We estimated N-UCAS O&S costs by analogy to F/A-18 E/F costs. The WBS for O&S, and the FY08 costs for F/A-18 E/F, obtained by Navy Visibility and Management of O&S Control (VAMOSC) are in Table 13.

Table 13. O&S Data for 2008 F/A-18 E/F in FY10 Dollars[46]

	F/A-18E 2008		F/A-18F 2008	
Element Level 3	**FY 10 Dollars**	**Count**	**FY 10 Dollars**	**Count**
1.1.1 Organizational Regular Military Personnel Costs	138,512,721		174,368,209	
1.2.2 Training Expendable Stores Costs	16,018,727		4,709,888	
1.2.3 Support Supplies Costs	41,377,638		43,843,424	
1.2.4 AVDLR Costs Total Regular	104,241,602		126,360,343	
1.2.5 Fuel Costs	113,568,826		145,085,257	
1.2.6 PCS Costs	2,384,273		2,754,750	
2.1.1 Intermediate Military Personnel Costs	44,946,364		59,337,578	
2.1.3 Intermediate Contractor Personnel Costs	167,607		205,723	
3.1.1 Organic Aircraft Rework Costs	3,505,889		4,215,996	
3.1.2 Commercial Aircraft Rework Costs	51,630		63,064	
3.3.1 Organic Aircraft Engine Rework Costs	51,208,054		76,677,655	
3.3.2 Commercial Aircraft Engine Rework Costs	333,083		498,750	

[46] Data generated through Navy Visibility and Management Operating and Support Costs, http://www.navyvamosc.com/ (accessed September 2009).

	F/A-18E 2008		F/A-18F 2008	
Element Level 3	**FY 10 Dollars**	**Count**	**FY 10 Dollars**	**Count**
3.4 NAPRA Costs	372,315		206,382	
3.6.1 Organic Aircraft Emergency Repair Costs	2,675,152		3,514,124	
3.6.2 Commercial Aircraft Emergency Repair Costs	48,228		58,911	
3.8 Support Equipment Maintenance Costs	2,020,121		2,467,530	
4.1.1 Subtotal Organizational FRS Personnel Costs	20,360,259		36,078,197	
4.1.2 Subtotal FRS Operations Costs	44,607,966		96,641,946	
4.2.1 Operational Training Costs	1,669,933		2,043,114	
4.2.2 Maintenance Training Costs	2,128,890		2,223,972	
5.1.2 Modification Spares Costs	1,985,708		2,425,496	
5.1.4 Modification Kits and Installation Costs	74,502,496		91,003,048	
6.1 Navy Engineering and Technical Services (NETS) Costs	935,485		1,142,673	
6.2 Contractor Engineering and Technical Services (CETS) Costs	1,238,164		1,512,389	
6.3 Publications Costs	311,353		380,310	
6.4.1 Program Related Logistics Costs	5,378,927		6,570,233	
6.4.2 Program Related Engineering Costs	2,580,509		3,152,031	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	838,438		1,129,650	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	801,194		1,663,501	
A1.1.1 Regular Aircraft Number- Navy		117		125
A1.2.1 FRS Aircraft Number- Navy		32		57
A2.1.1 Regular Annual Flying Hours—Navy		39,717		50,593
A2.2.1 FRS Annual Flying Hours—Navy		6,377		18,427
A5.1.1 Regular Barrels of Fuel Consumed—Navy		1,235,817		1,578,768
A5.2.1 FRS Barrels of Fuel Consumed—Navy		190,349		562,950
Sum:	678,771,552		890,334,144	

We arranged the WBS for O&S into three categories:

1. Manpower related
2. Flight Hour related
3. Number of Aircraft related

Tables 13–15 show these categorizations. Our estimation methodology assumed the following:

1. For manpower related, we estimated N-UCAS per aircraft as 70 percent of the corresponding F/A

18s cost per aircraft, with the exception of FRS manpower estimates that used 50 percent.[47]

2. For Flight Hour related, we estimated that the cost per flight hour was proportional to the cost per flight hour of N-UCAS.

3. For Number of Aircraft related, we estimated that the cost per aircraft was proportional to the cost per aircraft of N-UCAS.

The estimation also assumes that the first 12 aircraft will be operational for the first two years prior to setting up full rate production.

Table 14. Manpower Associated Line Items

1.1.1 Organizational Regular Military Personnel Costs
1.2.2 Training Expendable Stores Costs
1.2.3 Support Supplies Costs
1.2.6 PCS Costs
2.1.1 Intermediate Military Personnel Costs
2.1.3 Intermediate Contractor Personnel Costs
4.1.1 Subtotal Organizational FRS Personnel Costs
4.1.2 Subtotal FRS Operations Costs
4.2.2 Maintenance Training Costs
7.2.1 Contractor Logistics Support Costs—FRS—Navy

Table 15. Flight Hour Associated Line Items

1.2.4 AVDLR Costs Total Regular
3.1.1 Organic Aircraft Rework Costs
3.1.2 Commercial Aircraft Rework Costs
3.3.1 Organic Aircraft Engine Rework Costs
3.3.2 Commercial Aircraft Engine Rework Costs
3.4 NAPRA Cost
3.6.1 Organic Aircraft Emergency Repair Costs
3.6.2 Commercial Aircraft Emergency Repair Costs
3.8 Support Equipment Maintenance
6.4.1 Program Related Logistics Costs
6.4.2 Program Related Engineering Costs
7.1.1 Contractor Logistics Support Costs—Regular—Navy

[47] The estimation was used based on a 2:1 approximation of officer to enlisted cost. As the automation of the vehicles increases the amount of human integration will be reduced. N-UCAS sensors can be operated and monitored by enlisted personnel, with officers used for overall command and control.

Table 16. Number of Aircraft Associated Line Items

4.2.1 Operational Training Costs
5.1.4 Modification Kits and Installation Costs
6.1 Navy Engineering and Technical Services (NETS) Costs
6.2 Contractor Engineering and Technical Services (CETS) Costs
6.3 Publications Costs

A summary of the total F/A-18 E/F O&S costs and the associated calculated multipliers can be found in Table 17.

Table 17. Summary of F/A-18 E/F 2008 O&S Data and Multipliers

F/A-18 E/F	**2008**	
Element Level 3	**Constant FY 10 Dollars**	**Multiple**
1.1.1 Organizational Regular Military Personnel Costs	312880930	0.002
1.2.2 Training Expendable Stores Costs	20728615	0.002
1.2.3 Support Supplies Costs	85221062	0.002
1.2.4 AVDLR Costs Total Regular	230601945	2003.248
1.2.5 Fuel Costs	258654083	72.49509
1.2.6 PCS Costs	5139023	0.002
2.1.1 Intermediate Military Personnel Costs	104283942	0.002
2.1.3 Intermediate Contractor Personnel Costs	373330	0.002
3.1.1 Organic Aircraft Rework Costs	7721885	67.08033
3.1.2 Commercial Aircraft Rework Costs	114694	0.996351
3.3.1 Organic Aircraft Engine Rework Costs	127885709	1110.948
3.3.2 Commercial Aircraft Engine Rework Costs	831833	7.226167
3.4 NAPRA Costs	578697	5.027164
3.6.1 Organic Aircraft Emergency Repair Costs	6189276	53.76649
3.6.2 Commercial Aircraft Emergency Repair Costs	107139	0.930721
3.8 Support Equipment Maintenance Costs	4487651	38.98441
4.1.1 Subtotal Organizational FRS Personnel Costs	56438456	0.002
4.1.2 Subtotal FRS Operations Costs	141249912	0.002
4.2.1 Operational Training Costs	3713047	11217.66
4.2.2 Maintenance Training Costs	4352862	0.0015
5.1.2 Modification Spares Costs	4411204	13326.9
5.1.4 Modification Kits and Installation Costs	165505544	500016.7
6.1 Navy Engineering and Technical Services (NETS) Costs	2078158	6278.423
6.2 Contractor Engineering and Technical Services (CETS) Costs	2750553	8309.828
6.3 Publications Costs	691663	2089.616
6.4.1 Program Related Logistics Costs	11949160	103.8028
6.4.2 Program Related Engineering Costs	5732540	49.79881

F/A-18 E/F	2008	
Element Level 3	**Constant FY 10 Dollars**	**Multiple**
7.1.1 Contractor Logistics Support Costs—Regular – Navy	1968088	17.09686
7.2.1 Contractor Logistics Support Costs—FRS – Navy	2464695	0.0015
A1.1.1 Regular Aircraft Number- Navy		242
A1.2.1 FRS Aircraft Number- Navy		89
A2.1.1 Regular Annual Flying Hours- Navy		90310
A2.2.1 FRS Annual Flying Hours- Navy		24804
A5.1.1 Regular Barrels of Fuel Consumed – Navy		2814585
A5.2.1 FRS Barrels of Fuel Consumed – Navy		753299
Sum:	1.57 Billion Dollars	

Tables 18 through 27 summarize the O&S costs by line item for N-UCAS from 2013 through 2022.

Table 18. O&S Data for N-UCAS 2013 in FY10 Dollars

N-UCAS	2013	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	7940180.701	
1.2.2 Training Expendable Stores Costs	526043.4018	
1.2.3 Support Supplies Costs	2162709.731	
1.2.4 AVDLR Costs Total Regular	8360191.36	
1.2.5 Fuel Costs	9377187.299	
1.2.6 PCS Costs	130416.2937	
2.1.1 Intermediate Military Personnel Costs	2646480.703	
2.1.3 Intermediate Contractor Personnel Costs	9474.23565	
3.1.1 Organic Aircraft Rework Costs	279947.4924	
3.1.2 Commercial Aircraft Rework Costs	4158.090634	
3.3.1 Organic Aircraft Engine Rework Costs	4636339.903	
3.3.2 Commercial Aircraft Engine Rework Costs	30157.08761	
3.4 NAPRA Costs	20979.95166	
3.6.1 Organic Aircraft Emergency Repair Costs	224384.6284	
3.6.2 Commercial Aircraft Emergency Repair Costs	3884.193353	
3.8 Support Equipment Maintenance Costs	162694.2961	
4.1.1 Subtotal Organizational FRS Personnel Costs	1432275.016	
4.1.2 Subtotal FRS Operations Costs	3584589.912	
4.2.1 Operational Training Costs	134611.9758	
4.2.2 Maintenance Training Costs	78903.8429	
5.1.2 Modification Spares Costs	159922.8036	
5.1.4 Modification Kits and Installation Costs	6000200.991	
6.1 Navy Engineering and Technical Services (NETS) Costs	75341.07553	
6.2 Contractor Engineering and Technical Services (CETS) Costs	99717.93353	

N-UCAS	2013	
Element Level 3	Constant FY 10 Dollars	Count
6.3 Publications Costs	25075.39577	
6.4.1 Program Related Logistics Costs	1245.634067	
6.4.2 Program Related Engineering Costs	597.5856977	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	205.162326	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	44677.25076	
A1.1.1 Regular Aircraft Number- Navy		12
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		4173.317
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		129349.3
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	48.15 Million Dollars	

Table 19. O&S Data for N-UCAS 2014 in FY10 Dollars

N-UCAS	2014	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	7940180.701	
1.2.2 Training Expendable Stores Costs	526043.4018	
1.2.3 Support Supplies Costs	2162709.731	
1.2.4 AVDLR Costs Total Regular	8360191.36	
1.2.5 Fuel Costs	9377187.299	
1.2.6 PCS Costs	130416.2937	
2.1.1 Intermediate Military Personnel Costs	2646480.703	
2.1.3 Intermediate Contractor Personnel Costs	9474.23565	
3.1.1 Organic Aircraft Rework Costs	279947.4924	
3.1.2 Commercial Aircraft Rework Costs	4158.090634	
3.3.1 Organic Aircraft Engine Rework Costs	4636339.903	
3.3.2 Commercial Aircraft Engine Rework Costs	30157.08761	
3.4 NAPRA Costs	20979.95166	
3.6.1 Organic Aircraft Emergency Repair Costs	224384.6284	
3.6.2 Commercial Aircraft Emergency Repair Costs	3884.193353	
3.8 Support Equipment Maintenance Costs	162694.2961	
4.1.1 Subtotal Organizational FRS Personnel Costs	1432275.016	
4.1.2 Subtotal FRS Operations Costs	3584589.912	
4.2.1 Operational Training Costs	134611.9758	
4.2.2 Maintenance Training Costs	78903.8429	
5.1.2 Modification Spares Costs	159922.8036	
5.1.4 Modification Kits and Installation Costs	6000200.991	
6.1 Navy Engineering and Technical Services (NETS) Costs	75341.07553	
6.2 Contractor Engineering and Technical Services (CETS) Costs	99717.93353	
6.3 Publications Costs	25075.39577	

N-UCAS	2014	
Element Level 3	Constant FY 10 Dollars	Count
6.4.1 Program Related Logistics Costs	1245.634067	
6.4.2 Program Related Engineering Costs	597.5856977	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	205.162326	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	44677.25076	
A1.1.1 Regular Aircraft Number- Navy		12
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		4173.317
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		129349.3
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	48.15 Million Dollars	

Table 20. O&S Data for N-UCAS 2015 in FY10 Dollars

N-UCAS	2015	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	19850451.75	
1.2.2 Training Expendable Stores Costs	1315108.505	
1.2.3 Support Supplies Costs	5406774.326	
1.2.4 AVDLR Costs Total Regular	20900478.4	
1.2.5 Fuel Costs	23442968.25	
1.2.6 PCS Costs	326040.7341	
2.1.1 Intermediate Military Personnel Costs	6616201.758	
2.1.3 Intermediate Contractor Personnel Costs	23685.58912	
3.1.1 Organic Aircraft Rework Costs	699868.7311	
3.1.2 Commercial Aircraft Rework Costs	10395.22659	
3.3.1 Organic Aircraft Engine Rework Costs	11590849.76	
3.3.2 Commercial Aircraft Engine Rework Costs	75392.71903	
3.4 NAPRA Costs	52449.87915	
3.6.1 Organic Aircraft Emergency Repair Costs	560961.571	
3.6.2 Commercial Aircraft Emergency Repair Costs	9710.483384	
3.8 Support Equipment Maintenance Costs	406735.7402	
4.1.1 Subtotal Organizational FRS Personnel Costs	3580687.541	
4.1.2 Subtotal FRS Operations Costs	8961474.779	
4.2.1 Operational Training Costs	134611.9758	
4.2.2 Maintenance Training Costs	197259.6073	
5.1.2 Modification Spares Costs	399807.0091	
5.1.4 Modification Kits and Installation Costs	15000502.48	
6.1 Navy Engineering and Technical Services (NETS) Costs	188352.6888	
6.2 Contractor Engineering and Technical Services (CETS) Costs	249294.8338	
6.3 Publications Costs	62688.48943	
6.4.1 Program Related Logistics Costs	3114.085168	

N-UCAS	2015	
Element Level 3	Constant FY 10 Dollars	Count
6.4.2 Program Related Engineering Costs	1493.964244	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	512.9058151	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	111693.1269	
A1.1.1 Regular Aircraft Number- Navy		30
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		10433.29
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		323373.2
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	120.2 Million Dollars	

Table 21. O&S Data for N-UCAS 2016 in FY10 Dollars

N-UCAS	2016	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	35730813.15	
1.2.2 Training Expendable Stores Costs	2367195.308	
1.2.3 Support Supplies Costs	9732193.787	
1.2.4 AVDLR Costs Total Regular	37620861.12	
1.2.5 Fuel Costs	42197342.85	
1.2.6 PCS Costs	586873.3215	
2.1.1 Intermediate Military Personnel Costs	11909163.16	
2.1.3 Intermediate Contractor Personnel Costs	42634.06042	
3.1.1 Organic Aircraft Rework Costs	1259763.716	
3.1.2 Commercial Aircraft Rework Costs	18711.40785	
3.3.1 Organic Aircraft Engine Rework Costs	20863529.56	
3.3.2 Commercial Aircraft Engine Rework Costs	135706.8943	
3.4 NAPRA Costs	94409.78248	
3.6.1 Organic Aircraft Emergency Repair Costs	1009730.828	
3.6.2 Commercial Aircraft Emergency Repair Costs	17478.87009	
3.8 Support Equipment Maintenance Costs	732124.3323	
4.1.1 Subtotal Organizational FRS Personnel Costs	6445237.573	
4.1.2 Subtotal FRS Operations Costs	16130654.6	
4.2.1 Operational Training Costs	201917.9637	
4.2.2 Maintenance Training Costs	355067.2931	
5.1.2 Modification Spares Costs	719652.6163	
5.1.4 Modification Kits and Installation Costs	27000904.46	
6.1 Navy Engineering and Technical Services (NETS) Costs	339034.8399	
6.2 Contractor Engineering and Technical Services (CETS) Costs	448730.7009	
6.3 Publications Costs	112839.281	
6.4.1 Program Related Logistics Costs	5605.353302	
6.4.2 Program Related Engineering Costs	2689.135639	

N-UCAS	2016	
Element Level 3	Constant FY 10 Dollars	Count
7.1.1 Contractor Logistics Support Costs—Regular—Navy	923.2304672	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	201047.6284	
A1.1.1 Regular Aircraft Number- Navy		54
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		18779.93
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		582071.7
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	216.3 Million Dollars	

Table 22. O&S Data for N-UCAS 2017 in FY10 Dollars

N-UCAS	2017	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	47641084.21	
1.2.2 Training Expendable Stores Costs	3156260.411	
1.2.3 Support Supplies Costs	12976258.38	
1.2.4 AVDLR Costs Total Regular	50161148.16	
1.2.5 Fuel Costs	56263123.79	
1.2.6 PCS Costs	782497.7619	
2.1.1 Intermediate Military Personnel Costs	15878884.22	
2.1.3 Intermediate Contractor Personnel Costs	56845.4139	
3.1.1 Organic Aircraft Rework Costs	1679684.955	
3.1.2 Commercial Aircraft Rework Costs	24948.54381	
3.3.1 Organic Aircraft Engine Rework Costs	27818039.42	
3.3.2 Commercial Aircraft Engine Rework Costs	180942.5257	
3.4 NAPRA Costs	125879.71	
3.6.1 Organic Aircraft Emergency Repair Costs	1346307.77	
3.6.2 Commercial Aircraft Emergency Repair Costs	23305.16012	
3.8 Support Equipment Maintenance Costs	976165.7764	
4.1.1 Subtotal Organizational FRS Personnel Costs	8593650.098	
4.1.2 Subtotal FRS Operations Costs	21507539.47	
4.2.1 Operational Training Costs	269223.9517	
4.2.2 Maintenance Training Costs	473423.0574	
5.1.2 Modification Spares Costs	959536.8218	
5.1.4 Modification Kits and Installation Costs	36001205.95	
6.1 Navy Engineering and Technical Services (NETS) Costs	452046.4532	
6.2 Contractor Engineering and Technical Services (CETS) Costs	598307.6012	
6.3 Publications Costs	150452.3746	
6.4.1 Program Related Logistics Costs	7473.804403	
6.4.2 Program Related Engineering Costs	3585.514186	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	1230.973956	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	268063.5045	

N-UCAS	2017	
Element Level 3	Constant FY 10 Dollars	Count
A1.1.1 Regular Aircraft Number- Navy		72
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		25039.9
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		776095.6
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	288.4 Million Dollars	

Table 23. O&S Data for N-UCAS 2017 in FY10 Dollars

N-UCAS	2018	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	59551355.26	
1.2.2 Training Expendable Stores Costs	3945325.514	
1.2.3 Support Supplies Costs	16220322.98	
1.2.4 AVDLR Costs Total Regular	62701435.2	
1.2.5 Fuel Costs	70328904.74	
1.2.6 PCS Costs	978122.2024	
2.1.1 Intermediate Military Personnel Costs	19848605.27	
2.1.3 Intermediate Contractor Personnel Costs	71056.76737	
3.1.1 Organic Aircraft Rework Costs	2099606.193	
3.1.2 Commercial Aircraft Rework Costs	31185.67976	
3.3.1 Organic Aircraft Engine Rework Costs	34772549.27	
3.3.2 Commercial Aircraft Engine Rework Costs	226178.1571	
3.4 NAPRA Costs	157349.6375	
3.6.1 Organic Aircraft Emergency Repair Costs	1682884.713	
3.6.2 Commercial Aircraft Emergency Repair Costs	29131.45015	
3.8 Support Equipment Maintenance Costs	1220207.221	
4.1.1 Subtotal Organizational FRS Personnel Costs	10742062.62	
4.1.2 Subtotal FRS Operations Costs	26884424.34	
4.2.1 Operational Training Costs	336529.9396	
4.2.2 Maintenance Training Costs	591778.8218	
5.1.2 Modification Spares Costs	1199421.027	
5.1.4 Modification Kits and Installation Costs	45001507.43	
6.1 Navy Engineering and Technical Services (NETS) Costs	565058.0665	
6.2 Contractor Engineering and Technical Services (CETS) Costs	747884.5015	
6.3 Publications Costs	188065.4683	
6.4.1 Program Related Logistics Costs	9342.255503	
6.4.2 Program Related Engineering Costs	4481.892732	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	1538.717445	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	335079.3807	
A1.1.1 Regular Aircraft Number- Navy		90

N-UCAS	2018	
Element Level 3	Constant FY 10 Dollars	Count
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		31299.88
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		970119.5
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	360.5 Million Dollars	

Table 24. O&S Data for N-UCAS 2019 in FY10 Dollars

N-UCAS	2019	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	71461626.31	
1.2.2 Training Expendable Stores Costs	4734390.616	
1.2.3 Support Supplies Costs	19464387.57	
1.2.4 AVDLR Costs Total Regular	75241722.24	
1.2.5 Fuel Costs	84394685.69	
1.2.6 PCS Costs	1173746.643	
2.1.1 Intermediate Military Personnel Costs	23818326.33	
2.1.3 Intermediate Contractor Personnel Costs	85268.12085	
3.1.1 Organic Aircraft Rework Costs	2519527.432	
3.1.2 Commercial Aircraft Rework Costs	37422.81571	
3.3.1 Organic Aircraft Engine Rework Costs	41727059.13	
3.3.2 Commercial Aircraft Engine Rework Costs	271413.7885	
3.4 NAPRA Costs	188819.565	
3.6.1 Organic Aircraft Emergency Repair Costs	2019461.656	
3.6.2 Commercial Aircraft Emergency Repair Costs	34957.74018	
3.8 Support Equipment Maintenance Costs	1464248.665	
4.1.1 Subtotal Organizational FRS Personnel Costs	12890475.15	
4.1.2 Subtotal FRS Operations Costs	32261309.21	
4.2.1 Operational Training Costs	403835.9275	
4.2.2 Maintenance Training Costs	710134.5861	
5.1.2 Modification Spares Costs	1439305.233	
5.1.4 Modification Kits and Installation Costs	54001808.92	
6.1 Navy Engineering and Technical Services (NETS) Costs	678069.6798	
6.2 Contractor Engineering and Technical Services (CETS) Costs	897461.4018	
6.3 Publications Costs	225678.5619	
6.4.1 Program Related Logistics Costs	11210.7066	
6.4.2 Program Related Engineering Costs	5378.271279	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	1846.460934	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	402095.2568	
A1.1.1 Regular Aircraft Number- Navy		108
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		37559.85

N-UCAS	2019	
Element Level 3	Constant FY 10 Dollars	Count
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		1164143
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	432.6 Million Dollars	

Table 25. O&S Data for N-UCAS 2020 in FY10 Dollars

N-UCAS	2020	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	83371897.36	
1.2.2 Training Expendable Stores Costs	5523455.719	
1.2.3 Support Supplies Costs	22708452.17	
1.2.4 AVDLR Costs Total Regular	87782009.27	
1.2.5 Fuel Costs	98460466.64	
1.2.6 PCS Costs	1369371.083	
2.1.1 Intermediate Military Personnel Costs	27788047.38	
2.1.3 Intermediate Contractor Personnel Costs	99479.47432	
3.1.1 Organic Aircraft Rework Costs	2939448.671	
3.1.2 Commercial Aircraft Rework Costs	43659.95166	
3.3.1 Organic Aircraft Engine Rework Costs	48681568.98	
3.3.2 Commercial Aircraft Engine Rework Costs	316649.4199	
3.4 NAPRA Costs	220289.4924	
3.6.1 Organic Aircraft Emergency Repair Costs	2356038.598	
3.6.2 Commercial Aircraft Emergency Repair Costs	40784.03021	
3.8 Support Equipment Maintenance Costs	1708290.109	
4.1.1 Subtotal Organizational FRS Personnel Costs	15038887.67	
4.1.2 Subtotal FRS Operations Costs	37638194.07	
4.2.1 Operational Training Costs	471141.9154	
4.2.2 Maintenance Training Costs	828490.3505	
5.1.2 Modification Spares Costs	1679189.438	
5.1.4 Modification Kits and Installation Costs	63002110.4	
6.1 Navy Engineering and Technical Services (NETS) Costs	791081.2931	
6.2 Contractor Engineering and Technical Services (CETS) Costs	1047038.302	
6.3 Publications Costs	263291.6556	
6.4.1 Program Related Logistics Costs	13079.1577	
6.4.2 Program Related Engineering Costs	6274.649825	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	2154.204423	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	469111.1329	
A1.1.1 Regular Aircraft Number- Navy		126
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		43819.83
A2.2.1 FRS Annual Flying Hours- Navy		0

N-UCAS	2020	
Element Level 3	Constant FY 10 Dollars	Count
A5.1.1 Regular Barrels of Fuel Consumed—Navy		1358167
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	504.7 Million Dollars	

Table 26. O&S Data for N-UCAS 2021 in FY10 Dollars

N-UCAS	2021	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	95282168.41	
1.2.2 Training Expendable Stores Costs	6312520.822	
1.2.3 Support Supplies Costs	25952516.77	
1.2.4 AVDLR Costs Total Regular	100322296.3	
1.2.5 Fuel Costs	112526247.6	
1.2.6 PCS Costs	1564995.524	
2.1.1 Intermediate Military Personnel Costs	31757768.44	
2.1.3 Intermediate Contractor Personnel Costs	113690.8278	
3.1.1 Organic Aircraft Rework Costs	3359369.909	
3.1.2 Commercial Aircraft Rework Costs	49897.08761	
3.3.1 Organic Aircraft Engine Rework Costs	55636078.84	
3.3.2 Commercial Aircraft Engine Rework Costs	361885.0514	
3.4 NAPRA Costs	251759.4199	
3.6.1 Organic Aircraft Emergency Repair Costs	2692615.541	
3.6.2 Commercial Aircraft Emergency Repair Costs	46610.32024	
3.8 Support Equipment Maintenance Costs	1952331.553	
4.1.1 Subtotal Organizational FRS Personnel Costs	17187300.2	
4.1.2 Subtotal FRS Operations Costs	43015078.94	
4.2.1 Operational Training Costs	538447.9033	
4.2.2 Maintenance Training Costs	946846.1148	
5.1.2 Modification Spares Costs	1919073.644	
5.1.4 Modification Kits and Installation Costs	72002411.89	
6.1 Navy Engineering and Technical Services (NETS) Costs	904092.9063	
6.2 Contractor Engineering and Technical Services (CETS) Costs	1196615.202	
6.3 Publications Costs	300904.7492	
6.4.1 Program Related Logistics Costs	14947.60881	
6.4.2 Program Related Engineering Costs	7171.028372	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	2461.947913	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	536127.0091	
A1.1.1 Regular Aircraft Number- Navy		144
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		50079.81
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		1552191

N-UCAS	2021	
Element Level 3	Constant FY 10 Dollars	Count
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0
Sum:	576.8 Million Dollars	

Table 27. O&S Data for N-UCAS 2022 in FY10 Dollars

N-UCAS	2022	
Element Level 3	Constant FY 10 Dollars	Count
1.1.1 Organizational Regular Military Personnel Costs	107192439.5	
1.2.2 Training Expendable Stores Costs	7101585.924	
1.2.3 Support Supplies Costs	29196581.36	
1.2.4 AVDLR Costs Total Regular	112862583.4	
1.2.5 Fuel Costs	126592028.5	
1.2.6 PCS Costs	1760619.964	
2.1.1 Intermediate Military Personnel Costs	35727489.49	
2.1.3 Intermediate Contractor Personnel Costs	127902.1813	
3.1.1 Organic Aircraft Rework Costs	3779291.148	
3.1.2 Commercial Aircraft Rework Costs	56134.22356	
3.3.1 Organic Aircraft Engine Rework Costs	62590588.69	
3.3.2 Commercial Aircraft Engine Rework Costs	407120.6828	
3.4 NAPRA Costs	283229.3474	
3.6.1 Organic Aircraft Emergency Repair Costs	3029192.483	
3.6.2 Commercial Aircraft Emergency Repair Costs	52436.61027	
3.8 Support Equipment Maintenance Costs	2196372.997	
4.1.1 Subtotal Organizational FRS Personnel Costs	19335712.72	
4.1.2 Subtotal FRS Operations Costs	48391963.81	
4.2.1 Operational Training Costs	605753.8912	
4.2.2 Maintenance Training Costs	1065201.879	
5.1.2 Modification Spares Costs	2158957.849	
5.1.4 Modification Kits and Installation Costs	81002713.38	
6.1 Navy Engineering and Technical Services (NETS) Costs	1017104.52	
6.2 Contractor Engineering and Technical Services (CETS) Costs	1346192.103	
6.3 Publications Costs	338517.8429	
6.4.1 Program Related Logistics Costs	16816.05991	
6.4.2 Program Related Engineering Costs	8067.406918	
7.1.1 Contractor Logistics Support Costs—Regular—Navy	2769.691402	
7.2.1 Contractor Logistics Support Costs—FRS—Navy	603142.8852	
A1.1.1 Regular Aircraft Number- Navy		162
A1.2.1 FRS Aircraft Number- Navy		0
A2.1.1 Regular Annual Flying Hours- Navy		56339.78
A2.2.1 FRS Annual Flying Hours- Navy		0
A5.1.1 Regular Barrels of Fuel Consumed—Navy		1746215
A5.2.1 FRS Barrels of Fuel Consumed—Navy		0

N-UCAS	2022	
Element Level 3	Constant FY 10 Dollars	Count
Sum:	648.9 Million Dollars	

Table 28 summarizes the O&S costs for N-UCAS through the end of production in 2022.

Table 28. O&S Totals for N-UCAS by Year in Millions of FY10$

COST (FY10$ in Millions)	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Total O&S	48	48	120	216	288	360	433	505	577	649
O&S COST per Unit (N-UCAS)	4	4	4	4	4	4	4	4	4	4

E. SUMMARY

Table 29 summarizes the N-UCAS LCCE, in FY10$M through FY42, which is 20 past the end of the production phase. Each of the 20-out years was estimated using the FY22 O&S data.

Table 29. LCC for N-UCAS in Millions of FY10$

Total RDT&E Costs FY10$ in millions	1468.23
Total Production Costs in FY10$ in millions	5012.48
Total O&S Costs in FY10$ in millions	16224.44
Total LCC in FY10$ in millions	22705.15

V. COST ANALYSIS

A. INTRODUCTION

In this section, we analyzed the funding stream for N-UCAS through the entire production phase (FY13-FY22) by comparing it to the O&S of two aircraft carriers and their associated air wings. Two aircraft carriers and their associated air wings were chosen based on the constraining capacity of warhead tonnage on target (strike mission availability). This thesis approximated (as calculated in Chapter III) that an 18 N-UCAS addition to an aircraft carrier (six organic N-UCAS plus 12 land-based) can deliver the same warheads on targets as an additional strike air wing. This allows nine aircraft carriers to deliver the same amount of warhead tonnage as approximately 13 carriers. All other mission sets as outlined in Table 3 will be enhanced per Chapter III.

B. CARRIER AND AIR WING O&S

The class average for all CVNs O&S data was combined with the O&S data for the aircraft in the air wing. E-2C O&S data were used to approximate E-2D O&S, and Super Hornet data were used to approximate Growler and JSF O&S. Table 30 summarizes the O&S data for the complete air wing and carrier. The total was multiplied by two (to illustrate a reduction of two aircraft carriers) to show the total savings by reducing the carrier fleet to nine carriers.

Table 30. O&S Summary for One Equivalent Air Wing and Carrier[48]

O&S 2008 in millions of FY10$	Per Unit	Total per Air Wing		Total Cost
454.66	CVN-65CL			
403.09	CVN-68CL			
428.88	Average CVN O&S	1		428.88
7.90	E-2C	5		39.50
4.56	FA-18E			
4.89	FA-18F			
4.72	Average FA-18	24		113.37
4.72	JSF	24		113.37
4.72	Growler	5		23.62
			Total	718.74
			2 Carriers	1437.47

C. COST COMPARISON

Table 31 illustrates that if the reduction in the carrier fleet can be accomplished by 2013, cost savings will be realized.[49] In 2022, once production is complete, the O&S costs for the entire N-UCAS complement will be less than two air wings' and two carriers' O&S costs.

[48] Navy Visibility and Management Operating and Support Costs, http://www.navyvamosc.com (accessed October 2009).

[49] A reduction in one aircraft carrier will yield comparable savings to the increase in funding requirements from N-UCAS.

Table 31. O&S Funding for Two Air Wings and Carriers vs. Funding for the entire N-UCAS Project

COST (FY10$ in Millions)	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Total O&S	48	48	120	216	288	360	433	505	577	649
Total Production	450	601	761	553	543	535	528	523	518	
Total RDT&E	158									
Total Costs	656	650	881	769	831	895	961	1027	1095	649
Cost Savings from reduction in Carrier Fleet	1437	1437	1437	1437	1437	1437	1437	1437	1437	1437
Change in Funding	-781	-788	-557	-668	-606	-542	-477	-410	-343	-789

The computations above show that the LCCE developed in this thesis implies an overall savings in Navy Funding Requirements. To test the robustness of these savings, we increased “other production-costs.” Originally, these costs were estimated as a factor of manufacturing costs, so we increased the factor to 100 percent (thereby doubling other production-costs to equal manufacturing costs), which still returned a cost savings in funding requirements.

D. CONCLUSION

In addition to increasing the capacity for strike of a single air wing, N-UCAS will increase the carrier's capability to perform long-distance persistent strike. The Life Cycle Cost estimation demonstrates a reduction in spending through 2022. Also, the O&S data for the rest of the CSG (destroyers, cruisers, and submarines) while it is deployed with a carrier were not included. These costs are summarized in Table 32.

Table 32. O&S Costs associated with Cruisers, Destroyers, and Submarines for 2008 in Millions of FY10$[50]

Ship Class	**O&S Cost per Year (FY10$M)**
CG-47	54.7
DDG-51	39.4
SSN-688	54.3
Total for Two of each Ship for Six Months	148.4

Although the costs in Table 32 will not be saved by reducing the carrier fleet, the O&S costs can be spent on mission sets other than the protection of the carrier fleet.

[50] Navy Visibility and Management Operating and Support Costs.

VI. SUMMARY

A. CAPABILITIES

The addition of N-UCAS to the fleet will add the capability of long-range persistent strike. The current capability is limited by the flight hours a human can spend in the aircraft, while N-UCAS will increase flight hours to 50 hours. The 50–hour flight time, coupled with the long unrefueled ranges, will enable the fleet to meet the strike needs of the military in a surface denied domain.

B. CAPACITY

N-UCAS will allow the fleet to meet the constraining requirement of strike missions (warheads on targets) with nine aircraft carriers. The nine aircraft carriers with N-UCAS will deliver the equivalent of approximately 13 strike carriers (measured in warhead tonnage on target). The addition of the N-UCAS will increase the capacity of the fleet to perform all other mission sets, while reducing the cost to the military and allowing the opportunity to fund the MSCE portion of the fleet.

C. LCC ESTIMATION

The LCC show that the addition of N-UCAS will reduce cost to the Navy through FY22, if the aircraft carrier fleet is reduced to nine carriers. Although the carrier fleet is reduced, the destroyers, cruisers, and submarine associated with CSGs will be able to accomplish other missions such as MSCE, partnership building, strike, ASW, and ISR. Not only will these ships be able to accomplish MSCE and partnership building, but the reduction in funding

provides resources to fund an increase in procurement for smaller ships better suited for partnership building and maritime security.

D. CONCLUSION

The addition of N-UCAS will increase the fleet's capacities and capabilities. N-UCAS can be added to the fleet, giving an organic UAV capability to the carrier, while increasing power projection capacity and allowing for the reduction in the carrier fleet. The reduction in the carrier fleet will not reduce the capacity to perform any military functions—specifically the carrier fleet will be able to perform more ISR, strike, and close-in-air support than the current fleet.

The LCC estimation of N-UCAS illustrates that the Navy can fund the project with cost savings from the reduction in O&S costs associated with two aircraft carriers. This thesis has not analyzed the risks associated with reducing the carrier fleet associated with less presence, but the cost savings can be used to fund additional LCS and HSVs, which will enable a better-suited platform for MSCE.

VII. RECOMMENDATIONS

This thesis has demonstrated that the capabilities of the carrier fleet could be increased with the addition of N-UCAS, which support long-range persistent strike and ISR. With the addition of N-UCAS the capability and capacity of today's carrier fleet can be met with nine carriers. The carrier fleet is used as a show of force and Sea Control in the global commons, but the reduction in large expensive carriers will allow for funding of LCS and HSV type vessels that will aid in partnership building and maritime security. Further study is recommended in the following areas:

- An analysis of the addition of directed energy and lasers to N-UCAS to increase the strike capacity.
- The integration of unmanned underwater vehicles to aid in targeting and ISR for surface denied environments.
- LCC estimations for integration of N-UCAS into the EW and AEW air wings.
- Sensitivity Analysis of the number of carriers in the fleet to include:
    - Threat Analysis.
    - Cost Analysis of a brown and green water fleet.
- Building a new class of ship that is designed for unmanned vehicles as opposed to building unmanned vehicles to fit the current vessels.
- An analysis of manpower requirements for N-UCAS integration.
- Cost Estimations for the O&S data expended for other ships that are included in the CSG.

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APPENDIX A. ASSUMPTIONS

1. N-UCAS will have self protection in the form of lasers or directed energy by 2030.

2. JSF and Super Hornet 8000lb payload based on total 20,000lb payload. They must carry air-to-air missiles and external fuel bladders to perform mission sets as discussed.

3. Interdiction and fleet air defense (air-to-air combat) is conducted by manned fighters.

4. JSF and Super Hornet lose stealth when loaded with external payloads.

5. N-UCAS can be equipped with payloads equivalent to the capabilities of the E-2D and the Growler, with the exception of the supersonic speed of the Growler. (Not used for cost estimations)

6. Once the target location is outside 400nm from the aircraft carrier, Air Force support is needed to keep the aerial tanker within 200nm of the target. This could place the tanker in the threat envelope.

7. The aircraft speed to and from the target to the carrier and to and from the tanker is maximum aircraft speed. (After burner not analyzed).

8. Loiter times over target are calculated using an approach speed of 125kts.

9. Manned aircraft are limited to 10-hour flights due to human restrictions.

10. Tanking time is approximated at 20 minutes for rendezvous, loiter, approach, and tanking.

11. The aircraft tank after launch and before return so the missions are started with full tanks.

12. Fuel burn rates were not increased for operation with after burner.

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APPENDIX B. CALCULATIONS

1. Distance from carrier to target is 0 to 3000nm.

2. $$Time\ to\ Target = \frac{\text{Distance from Carrier}}{Maximum\ Speed}$$

3. $Tanker\ Distance\ from\ Target = \frac{Distance\ from\ Carrier2}{\ }$: Until Assumption #7 becomes relevant

4.
$$Tanker\ Time = 2 \times (Maximum\ Speed \times Distance\ from\ Tanker) \mid 20 minutes$$

5.
$$Total\ Times\ Aircraft\ needs\ to\ refuel = \frac{\text{(Time carriertotarget + Tanker Time)xMax Speed + (Total Flight Time} - \text{(Time carriertotarget + Tanker Time}}{\text{maximum combat radius}}$$

Total Flight Time is 50 hours for N-UCAS and 10 hours for JSF and Super Hornet.

6.
$$Time\ on\ Station = \text{Total Flight Time} - (\text{Total times aircraft needs to tank} \times \text{Tanker Time} + \text{Distance from Carrier} \times 2)$$

x2 is for back and forth to the carrier

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